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ESTON MONOGRAPHS

B–1 Entitled

A FEW SUGGESTIONS RELATING TO THE SELECTION OF ELECTRICAL MEASURING INSTRUMENTS

B–2 Entitled

ELEMENTARY ELECTRICAL TESTING IN THE HIGH SCHOOL LABORATORY

LIBRARY OF THE UNIVERSITY OF CALIFORNIA

B–3 Entitled

PRACTICAL MEASURING APPARATUS

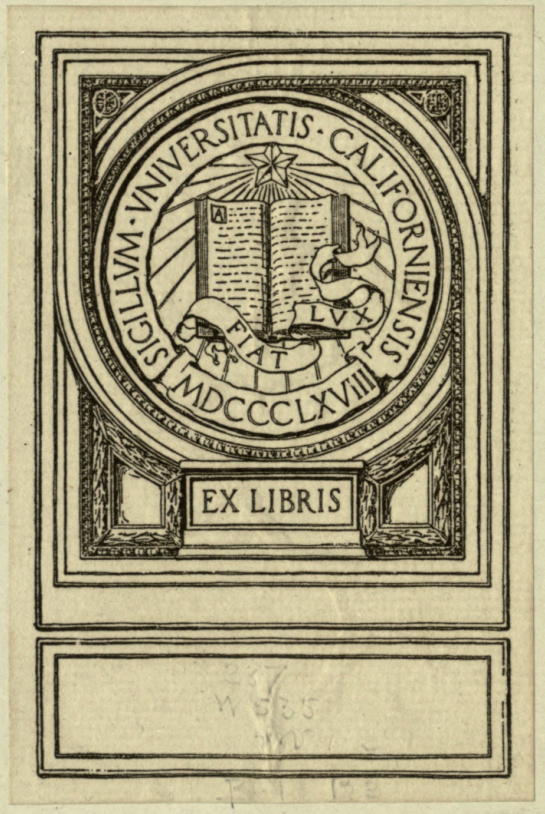
SECOND EDITION

Combined under one cover for the convenience of SCIENCE TEACHERS in HIGH SCHOOLS and COLLEGIATE PREPARATORY SCHOOLS

COMPLIMENTS OF

Veston Electrical Instrument Company

NEWARK, N. J.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A FEW SUGGESTIONS RELATING TO THE SELECTION OF ELECTRICAL MEASURING INSTRUMENTS

FOR USE IN THE LABORATORIES OF HIGH SCHOOLS AND COLLEGIATE PREPARATORY SCHOOLS

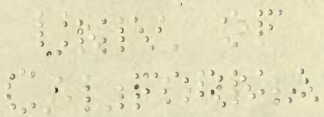
MONOGRAPH B-1

SECOND EDITION, AUGUST, 1914

ISSUED FOR

SCIENCE TEACHERS IN EDUCATIONAL INSTITUTIONS

"If one were called upon to name a single word which, more than any other, is the keyword to modern science, one would be tempted to say that 'quantitative' is that word. Measuring, weighing, counting—these and the perfection of the processes concerned with them have been the foundation of that magnificent advance of the sciences which is the most distinguishing characteristic of the modern world."



WESTON ELECTRICAL INSTRUMENT CO.

NEWARK, N. J.

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PREAMBLE

MONOGRAPHS B1, B2 and B3, now combined under one cover, were originally issued separately.

The object of this Company in preparing and distributing these and subsequent monographs, is to endeavor to prove of material assistance to the Science Teachers of this country in matters pertaining to electrical experiments and electrical apparatus in the laboratories of High Schools and Collegiate Preparatory Schools.

Monograph B1 was first issued in an edition of 10,000 in 1913.

Monograph B2 and B3 combined was also originally issued in an edition of 10,000, and a revised edition of B2, entitled "Monograph 2, Joint Committee Series," was later formally adopted by the National Education Association, and under its auspices a special edition of 10,000 was prepared and distributed with the 1913 report of its proceedings.

The increasing demand for copies of these Monographs has necessitated the preparation of this edition, and for the conv nience of Science Teachers we have combined the three publications under one cover.

In this combined second edition we have revised the text to some extent, improved the illustrations and added a few new models of instruments to those originally recommended in Monograph B3.

In all other essential details it conforms to the prior editions, and, as has previously been the case, it is distributed gratuitously.

We desire to express our appreciation of the interest manifested in these publications by Science Teachers and also wish to state that Monograph B4 is available upon request.

New Monographs will be prepared as rapidly as interesting and pertinent matter can be accumulated.

To promote this end, we once more urge instructors to

337702

cooperate with us by contributing exercises in electrical measurements performed by students.

It may be of interest to Science Teachers to note that there is still available for distribution a limited supply of a set consisting of two large laboratory wall charts illustrating the principle of operation and method of construction of Weston Direct Current Switchboard Instruments.

WESTON ELECTRICAL INSTRUMENT COMPANY.

JOINT COMMITTEE ON PHYSICS

J. A. RANDALL, PRATT INSTITUTE, BROOKLYN, N. Y.
W. R. PYLE, MORRIS HIGH SCHOOL, N. Y. CITY
GEO. A. WORKS, 843 STATE STREET, MADISON, WIS.
P. B. WOODWORTH, LEWIS INSTITUTE, CHICAGO, ILL.
F. H. BEALS, BARRINGER HIGH SCHOOL, NEWARK, N. J.
E. E. BURNS, JOSEPH MEDILL HIGH SCHOOL, CHICAGO
W. E. TOWER, ENGLEWOOD HIGH SCHOOL, CHICAGO
C. M. WESTCOTT, HOLLYWOOD HIGH SCHOOL, LOS ANGELES, CAL.
DR. W. A. HEDRICK, MC KINLEY MANUAL TRAINING SCHOOL, WASHINGTON, D. C.

OFFICE OF THE CHAIRMAN

BROOKLYN, N. Y., January 3, 1913.

FILE No.
CAT'G No.
JAN -4 1913
RECEIVED
ASST.

Mr. Caxton Brown, Sales Manager,
Weston Electrical Instrument Company,
Newark, N. J.

My dear Mr. Brown:

I have been very much impressed with my recent visit to your factory and I wish it were possible to place before the National Educational Association and the American Federation, the information I then received.

If you will get out and distribute to the teachers a pamphlet descriptive of your plant and if you will in addition send teachers copies of direction sheets as to how your instruments are used in various schools, you will be doing the teachers and schools a real service.

We agree that it would be of the greatest value to teachers if you would inform them fully on the following points:-

1st: Since the character of your product is such as to make one expect to find a large amount of hand work in its construction, will you show to what extent jigs, fixtures and automatic machinery are used in its manufacture?

2d: Will you inform us as to the changes in methods of manufacture? Except as we become acquainted with factories such as yours, we do not become sufficiently aware of the rapid changes in the character of the operations by which familiar objects are manufactured. The exteriors of these objects frequently do not change from their familiar appearance, while the processes of manufacture undergo radical changes.

3d: Will you inform us as to your welfare work? The light, clean, dustless buildings, the neat operators and the appointments of your club for employees, testify to the breadth of your business policies far better than any written words.

I personally have used your instruments for many years.

Very truly yours,

John A. Randall.

ELECTRICAL MEASURING INSTRUMENTS

There is printed on page 5 a copy of a letter received from Mr. John A. Randall of the Pratt Institute of Brooklyn.

Mr. Randall is chairman of the committee appointed to hasten the evolution of physics teaching. The special problem in which he is at present interested is that of the equipment of the laboratories of the High Schools. In the course of his investigation of what commercial electrical measuring instruments are best adapted to school use, he visited our factory.

We were very much pleased to receive subsequently the letter to which we have directed attention, because it suggested that we might be of service to the science teachers in High Schools if we made it easy for those who were sufficiently interested to obtain reliable and thorough information concerning the essential characteristics and methods of construction of the highest grade electrical measuring instruments.

The idea of preparing such information was not entirely novel, inasmuch as our sales representatives had often written to us of visits made to teachers in High Schools in their localities, and had frequently quoted their opinions, but we had hesitated to attempt to send out any publications until the receipt of of Mr. Randall's letter, which indicated the form in which the teacher would most appreciate receiving the information.

We shall therefore endeavor to comply with his request, but in order to be of the greatest service to science teachers we consider it advisable to separate our subjects and treat them in a series of monographs.

The Scope of this Monograph. This monograph is merely intended to set forth a few general remarks relating briefly to the new progressive movement among science teachers and for the purpose of submitting a few arguments in behalf of the selection of high-grade electrical measuring instruments as a part of the laboratory equipment.

It has also been prepared for the purpose of ascertaining whether the majority of teachers will actually welcome subse-

quent information that will enable them to acquire a more or less complete comprehension of the problems encountered in the production of really serviceable instruments, the best methods of adapting them to their requirements, and a means of ascertaining whether it will be of distinct advantage to themselves and their pupils to use the best instruments that are procurable, instead of the types of instruments that have heretofore been most generally used in the High School laboratories.

THE OPINION OF AN AUTHORITY

Recently one of the highest authorities on educational matters expressed himself to our sales manager in substantially the following words:

"The value of a course in physics in the High School depends greatly upon the manner in which a teacher has prepared himself to instruct the students.

"But no matter how conscientiously the teacher has prepared himself, he is fearfully handicapped unless his laboratory equipment includes the proper apparatus to allow him to perform his experiments in an interesting and, therefore, a forceful and appealing manner.

"It is true that our laboratory equipment has in the vast majority of schools been extremely poor, and it is not exaggeration to state that inadequate experiments have been conducted with crude apparatus for several decades.

"No greater misfortune could have transpired; but fortunately an era of awakening has recently dawned, and the progressive teachers are leaving the rut in which we have all been moving, and will no longer neglect educational progress in elementary physics or other lines of practical utility.

"Our industrial betterment has been chiefly dependent upon the ever-increasing practical application of science to the commercial arts, and the mistake that most of us have made is to have failed to appreciate the significance of that fact.

"Moreover, many of us have labored under the delusion that the underlying laws and principles relating to scientific matters are profound and perplexing, while the truth of the matter is that they are extremely simple to understand pro-

viding they are explained in a lucid, interesting, and impressive manner.

Development of Common-sense. "Elementary science courses should be so planned as to stimulate and develop sound common-sense and judgment relating to the matters dealt with. Youth is so impressionable and receptive that actual practical experience in making experiments with real instead of pseudo-real apparatus is of inestimable advantage.

Practice and Theory. "While the pupil is acquiring his practical knowledge, through using his own mind and hands, he will be forced to ask questions, and then is the time that the theory of the experiment should be expounded. That is, practice should be of equal, if not of greater, importance at this stage than theory, though of course the two should never be separated.

"It is fortunately becoming generally accepted that practical work is of vital importance, and the best authorities are continually emphasizing the necessity of encouraging, yes, insisting, that the students shall perform their experiments with real apparatus identical with the types they will use later in practical commercial work. Consequently, they are using every effort to discourage the use of the makeshift apparatus that several dealers and manufacturers have prepared and advocated for many years past."

In that excellent book, "The Teaching of Physics," by Prof. C. R. Mann, and in almost every number of "School Science and Mathematics," teachers will find the ideas we have quoted crystallized and expounded. In fact, it is now difficult to pick up any periodical or attend any lecture or conference dealing with educational matters without finding the same thoughts reiterated, and the intense concentration on the subject is rapidly accomplishing the end that is sought.

HISTORICAL

It is of interest to refer briefly to the influence of accurate electrical measuring instruments upon the development of the electrical industry in general.

What Accurate Instruments Mean to the Electrical Engineer. Before dependable electrical instruments became available,

the electrical engineer was in substantially the same position as the civil engineer would be to-day were he called upon to design and construct a steel railway bridge without the assistance of reliable standards of length, weight, tensile strength and resistance of the material he intended to use; or as the astronomer of to-day without his high-powered lenses, or the bacteriologist without his microscope, or the mariner without his sextant.

Prior to 1888 the types of electrical measuring instruments at the disposal of scientific workers, or those engaged in the practical applications of electricity to commercial and industrial purposes, were far from satisfactory.

In fact if we except the tangent galvanometer, which was reliable for accurate results only when used with the greatest care, and was not at all adapted to ordinary commercial work, there were no switchboard or portable instruments that met practical requirements.

Those who were engaged in electroplating, electrotyping, electrometallurgy, electric lighting, electric transmission of power, electric telegraphy, etc., keenly felt the need of instruments better adapted to the measurement of current strength and electromotive force than any instrument then known. So pressing was this demand in the exacting requirements of practical and scientific work that a myriad of processes, pieces of apparatus and applications of electricity that have now been brought to so high a state of efficiency, were practically held in suspense, because there were no adequate means of precisely measuring the electrical forces dealt with.

Speaking as a class of such instruments as were then in vogue, it may be said that they were in reality nothing better than mere indicators of the values they were intended to measure, and substantially all of them were crudely designed and constructed.

But the advent of the Weston permanent-magnet moving-coil type of instrument in 1888 changed all this.

Although a number of distinguished scientists in several countries were endeavoring to solve the problem of producing a type of instrument that would be accurate, direct reading, and convenient to use under all the conditions of practical work, Edward Weston was the only one to attain this end.

He was the first to employ a practically closed magnetic

field, and a uniform field in an electrical measuring instrument, and to produce an instrument that had a long uniform scale and was direct reading, accurate, and convenient to use. He also secured excellent control of the moving system, so that the pointer almost immediately came to rest at the true indication when large or small changes in current strength or electromotive force occurred, irrespective of whether the fluctuations of the circuits were rapid or slow.

Broad basic patents were granted to him for these inventions, and simple as his new type of instrument seemed to be after the problem was solved, the development of it was a feat of tremendous import to all users of electricity.

Then, for the first time, commercial instruments of a type and form that met all the urgently needed requirements were available, and it is no exaggeration to state that the unparalleled impetus given to matters pertaining to the development of the electrical industry was due chiefly to the new means of measurement and the precise determinations it made possible.

Why Handicap Students? Bearing this sketch of the importance of the revolution of the art of electrical measurement in mind, does it not seem a step in the wrong direction to handicap students by not giving them reliable and dependable instruments?

Is it not indeed somewhat similar to training an army of recruits with medieval crossbows and expecting them to do the duty of an army of regulars equipped with modern repeating rifles, or to training a class of students in an agricultural college to plow with a pointed stick when the implement which will later be placed in their hands is a modern plow?

There is no sound reason why pupils should not, and every reason why they should, be trained with the same apparatus they will use in practical work after leaving the school.

EXTENT OF THE USE OF WESTON INSTRUMENTS

As this monograph is prepared for the purpose of interesting and serving those teachers of science whose location prevents us from sending a representative from one of our district offices, it is not amiss to state that already Weston instruments (the

world's standards) are widely used in High School laboratories of our larger centers, and are also being adopted in the smaller schools whose teachers have had an opportunity of becoming conversant with the advantages to be derived from their use.

For instance:

In New York City we find Weston instruments in service in

Stuyvesant High School
Wadleigh High School
DeWitt Clinton High School

In the Borough of Brooklyn, in

Erasmus High School
Commercial High School
Manual Training School, and
Girls' High School — Just ordered 40 Instruments

In Jersey City they are in use in

Wm. L. Dickinson High School

In Plainfield, N. J., in

Plainfield High School

In East Orange, N. J., in

East Orange High School

In Philadelphia, in

Central High School

In Washington, in

McKinley High School
Manual Training Schools

In Buffalo, in,

Masten Park High School

(A letter addressed to the science teacher of any of the above schools will undoubtedly enable any teacher to obtain full information regarding the kind of service to be obtained from the use of Weston instruments.)

These few schools are merely indicative of the character of school in which Weston instruments are used, but a more significant fact is that practically every college or university in the United States adopts and uses them in preference to any other type marketed.

Use by the United States Government. Weston apparatus is used by the United States Government throughout its various branches, such as the army, navy, Isthmian Canal Zone, standardization laboratories, training schools, etc. It is manifestly impossible to make any definite statement as to the proportion Weston instruments bear to the total number of indicating electrical measuring instruments used by the Government, but we believe it to be a conservative statement that at least two-thirds of the direct-current instruments are of Weston manufacture, the remainder comprising, of course, instruments of substantially all other makes.

Likewise, Weston instruments, or imitations thereof, will be

found to preponderate in practically all certification laboratories throughout the civilized world.

Weston Instruments in Use in New York City. In New York City 85 per cent of the isolated plants in office buildings, hotels, etc., are equipped with Weston switchboard and portable instruments.

The foregoing facts are presented merely to explain to what extent the student, as a practical man, will encounter Weston instruments in after life.

A SUGGESTION

How the Teacher can Convince Himself. We are convinced that, if any teacher will ask any typical electrical engineer to advise him the make or type of instrument that is standard, Weston instruments will be recommended; and we are equally convinced that if any teacher who is earnest in his endeavor to improve his course and equipment will carefully note the character of instrument the school supply dealers generally advocate, and will then spend one or two hours visiting electric plants, laboratories or manufacturing establishments using electrical power in his neighborhood, he will agree that it requires a most fertile imagination to find any similarity between those dealers' instruments and the ones found and used in the commercial establishments to which we refer.

A trip of such a character will be more convincing than volumes of arguments we might set forth.

REASONS WHY INFERIOR INSTRUMENTS HAVE BEEN IN USE

We have stated there is no sound reason why instruments similar to those met with in after life should not be used in the schools, despite the fact that it is easy to understand why inferior contrivances have obtained so strong a foothold.

The Attitude of the School-supply Dealer. Most school-supply dealers have for years assumed that almost any kind of electrical measuring instruments would be acceptable to, or tolerated in school laboratories, and hence have manufactured or

marketed the abortive measuring contrivances to which we parti ularly refer. Because they required no ingenuity to devise, and cost little to make, they could be sold at a lower price than really serviceable instruments and still assure the purveyors a handsome profit.

However, there are at least two dealers who have pursued the contrary course and who have been primarily interested in selling apparatus of real merit to science teachers. In justice to these exceptions we should like to mention their names, but unfortunately cannot do so without risk of having our motive misinterpreted.

To a certain extent the responsibility for the continued sale of unsatisfactory instruments has been due to illustrations and descriptions which have appeared in text books, because the fact that such inferior contrivances have been given this unwarranted consideration has naturally led dealers to conclude that a demand for them existed, and also misled science teachers into assuming that they had merit.

The Last Stand of the Dealers' Instrument. It is a fact that there has been practically NO OTHER OUTLET for these wretched indicating contrivances than through the SCHOOLS, and were it not for conditions we have referred to, such makeshift instruments would long since have disappeared from that market.

Cost. The lure of the slightly lower original cost of an instrument is undoubtedly a great inducement to a teacher, because it allows him to spread his limited appropriation over more equipment; and is an inducement to a Board of Education purchasing department, because it examines prices and is apt to be primarily governed by price, unless the teacher makes specific recommendations.

Quality Preferable to Quantity. It is better, however, to have quality at a slight sacrifice of quantity in laboratory equipment, and it is also much cheaper to have quality, especially when considering electrical measuring instruments.

The fallacy of the idea that the inferior apparatus is more economical is best understood by considering the life of a poor and a good instrument and thus obtaining a knowledge of the cost of each per year of service.

Objections to the Tangent Galvanometer. In such a com-

parison the suspension type of tangent galvanometer can be briefly dispensed with, because the objections to it are numerous for High School use. It is extremely easy to injure; it consumes much time in reading that can be devoted to other purposes; it is difficult to read closely; it requires adjustment of the plane of its coil in the magnetic meridian; it is sensitive to stray magnetic fields and has a multiplicity of binding posts; *and the probabilities are that the average man will never be called upon to use anything like it after graduation.*

In fact, high-grade voltmeters and ammeters are decidedly preferable to tangent galvanometers for every purpose for which the latter instruments are used in High School laboratories. They have none of the objectionable features of galvanometers, and will, moreover, be of the greatest service for many tests and purposes to which the galvanometer is in no wise adapted.

Instruments of Quality are not High-priced. Standard Weston Voltmeters may be bought from about $10.50 upwards, depending upon the size and range, and upon whether switchboard or portable models are required, and these voltmeters are identical with those used in every-day practical commercial work. (See the article on p. 772 of " School Science and Mathematics " for December, 1912, written by C. L. Vestal of Carl Schurz High School, Chicago.)

FOOL-PROOF INSTRUMENTS

Due perhaps to arguments advanced by some makers in behalf of certain types of instruments they specifically recommend for school purposes, many teachers will be inclined to ask whether a high-grade instrument is fool-proof.

" Fool-proof " is a rather misleading term, and the question is naturally invoked : " Is any instrument ' fool-proof '? " The term " fool-proof," as applied to the instruments to which we have reference, is a cloak designed to cover a multitude of imperfections, chief among which are ill-designed, cumbersome parts that give rise to an unwarranted semblance of strength. The fallacy of asserting that heavy parts necessarily imply strength and durability is the usual refuge of the ignorant and the unskilled.

But is any apparatus fully "fool-proof"? Is any of the paraphernalia of the chemical laboratory proof against unreasonable or unintelligent use? Is it not necessary to give instruction regarding the proper use of such apparatus and then insist that instructions be observed?

Are watches, thermometers, chemical balances, or are any mechanical or electrical contrivances non-destructible when subjected to unreasonable use?

Is "fool-proof" really a fair term to apply to an electrical measuring instrument, or to any other appliance or material placed in the hands of students?

Is it not preferable to proceed on the basis that we are dealing with sound, healthy young minds of average intelligence, and then bend every effort to stimulate that intelligence and foster its expansion? Should we not carefully explain to the students the reason for making certain connections to an electrical measuring instrument and thus instill in their minds the necessity of exercising care in all their experiments, in order to promote self-reliance, and as we cultivate intelligent thought and sound reasoning, do we not pave the way to higher education?

If we give pupils apparatus that may be grossly abused without being damaged, we invariably do so at the sacrifice of certain good qualities that the apparatus should possess, and moreover, we encourage laxity and carelessness—characteristics which are extremely detrimental in school and in after life.

To answer then the question: "Is a high-grade instrument 'fool-proof'?"—we must reply, "Not wholly"; but we do lay particular stress on the fact that all Weston instruments are so designed that they will withstand overloads of several hundred per cent of the quantity represented by their full scale indications, and upon the fact that this extremely reasonable factor of safety is imparted without sacrificing any of the qualities which render the instruments thoroughly accurate, reliable and durable.

It, therefore, follows that if any Weston instrument be inadvertently connected in a circuit of unknown value, a very exceptional safeguard is afforded the user against damage to his property.

Moreover, if ordinary instructions be given to the students relating to wiring diagrams and with respect to explaining the functions of instruments, the only probability of damage is that

due to human fallibility, because every multiple range Weston instrument has each binding post distinctly marked to indicate the upper value of the range or scale to which it affords a means of connection.

If teachers desire the benefit of our experience in order to assist them in giving proper instructions to students, we shall be glad to extend our best support upon request.

The other day a science teacher, who has insisted upon the use of high-grade instruments in his laboratory, told us that he freely placed these instruments at the disposal of his first-year students and had yet to experience any damage to any instrument, despite the fact that he had merely given them ordinary instructions with regard to their use and the connections to be made—in fact, the same instructions as he would have given had he been dealing with inferior instruments.

THE TEACHER IS DEPENDENT UPON MANUFACTURERS' REPRESENTATIONS

Because it is true that teachers and departmental purchasing agents are to a great extent at the mercy of the instrument manufacturer, in the sense that they are compelled to base their judgment upon statements or claims made by representatives, or catalogues sent out by manufacturers, it is pertinent to say a few words about indicating electrical measuring instruments in general.

As we have intimated, one of the greatest safeguards to the teachers is the reliability and responsibility of the manufacturer.

The Value of a Reputation. A concern which has conscientiously conducted a business for over a score of years, and which, during that time, has built up a world-wide reputation for the highest quality of product and for fair dealing in the sense of stinting neither time nor money to improve its product in every possible manner—and then standing back of that product—naturally inspires confidence, because under no circumstances would it consent to jeopardize that reputation by making statements that could not be thoroughly substantiated by facts.

Such a record is that which the Weston Electrical Instrument Company enjoys, and we refer to it merely to give force to the

statement that is to follow, viz.: that substantially every type of indicating electrical measuring instrument to be found on the market to-day is either an imitation of an existing type of Weston instrument, or a development of a type that was devised by, or thoroughly and painstakingly analyzed by, this Company and discarded because unworthy of perpetuation when tested in the crucible of practical and commercial work.

Proper Development of an Instrument. The only honest or proper method of developing and manufacturing a thoroughly reliable type of electrical measuring instrument is to proceed strictly on the line of doing all the experimental work at the expense of the manufacturer and not at the expense of the user. In other words, to refrain from selling an instrument until it is known that it will fully meet the rigorous requirements imposed by actual practical service, and will therefore be so durable, generally serviceable, and accurate, that it will never be relegated to the scrap-heap.

To assure these qualities it is absolutely imperative to spend large sums of money in order to conduct most elaborate experiments with the object of properly solving all the many and complex problems encountered in the development of the best possible form of the instrument under consideration. After it becomes certain that no further advance can be made in the betterment of the type or form, it then becomes necessary to devise the best manufacturing methods for the production of the composite parts in such manner that they will be absolutely interchangeable, and so ensure perfect uniformity of product and prompt and economical repairing if abused.

Interchangeable Parts. All parts of Weston instruments are made strictly to gauge and are made by special tools, jigs, fixtures, etc., all of which call for a tremendous investment before a type is marketed; but as previously stated, unless such a policy is rigidly adhered to, it is impossible thoroughly to safeguard the buyer.

The Guise under which a Poor Instrument is Offered. It is comparatively easy for any manufacturer to make a type of indicating electrical measuring instrument that will initially conform with reasonable accuracy to certain simple tests. In fact, a manufacturer would be foolish to attempt to market a type which would not, under superficial examination, appear

to be fairly accurate. However, the determining qualification of an electrical instrument is its ability to retain its accuracy day in and day out when subjected to ordinary use and abuse and still be of a type that is flexible in its application and hence highly serviceable.

(As an illustration of what we mean by continued service, we submit that Mr. Randall of Pratt Institute informs us that there are certain Weston instruments in the Institute laboratories that have been in daily use for over ten years and are still rendering the same efficient service as when originally procured. Much more impressive illustrations could be cited.)

Movable Coil Types of Instruments. Many types of instruments, including Weston, have pivoted movable elements.

Such instruments may have many vital component parts, each of which should be most conscientiously designed and prepared. There are, for instance, magnets, springs, steel pivots, jewels, resistor wires, etc.

An Instrument, Like a Chain, is no Stronger than its Weakest Link. Unless these parts are designed and constructed in a most painstaking manner, each is subject to variation. Magnets may not be properly hardened or treated, or may be given such air clearances as to subject them to change in strength. Springs may not be properly tempered or of proper material to allow them to remain constant. Pivots may be too soft or have too large an area of contact. Jewels may be of poor quality (in many cheap instruments agate is substituted for jewels) and may be rough, pitted or cracked. Resistor wires, unless properly aged, are prone to change with time, and, if not made of special alloys, have serious changes in value with changes of temperature.

Light Weight on the Pivots and Jewels. But aside from these pitfalls encountered in mediocre instruments, any of which may mean loss of service or at least undependable service, no electrical measuring instrument may be made accurate, serviceable and durable unless its movable element is designed so as to have the lowest possible weight consistent with a sufficient strength and an abundant factor of safety to continually perform its functions under all the trying conditions of practical use.*

*See letter from Mr. H. W. Price, of Toronto University, which is reproduced near the end of this monograph.

In other words really meritorious instruments must be built with infinite care, and their production is fully as exacting as watch-making of the highest grade.

Friction. Friction, the tendency of the pointer to stick at certain parts of the scale, is generally due to wear and tear on pivots or jewels, or to dirt which may enter the instrument. The wear and tear on pivots and jewels is prodigiously in excess of any direct comparison of the weights of any two movable elements, and is enormously increased if a movable coil is not properly damped (made dead beat). Therefore, a movable coil which oscillates excessively before coming to rest, imposes detrimental wear on the pivots and jewels.

(The various essentials of a high-grade instrument are so numerous that they require a much more complete exposition than can be given in this monograph, which is intended merely as a foreword to teachers advising that we are anxious to be of service to them.)

To proceed, then, we confine ourselves to the statement that the types of instruments that have been most commonly used in the High Schools are in reality poor toys, designed without regard for accuracy, without regard for durability, and without regard for utility. In a word, they give rise to misinformation and trouble.

Investigation Worth While. If teachers will investigate the mechanical and electrical contrasts between these poor instruments and the highest grade instruments, and will familiarize themselves with the exceedingly slight difference in original purchase price, they will soon perceive that loss of service, cost of maintenance and renewals of inferior instruments run up their cost so rapidly as to make them vastly more expensive to use than a high-grade instrument built for continued service.

As a final word on this subject we give one more quotation from a well-known science teacher:

"A very serious objection to the use of the types of instruments that have been most commonly used in our laboratories is the difficulty experienced in getting the same reading upon repetition of the same test.

"This naturally creates doubt in the mind of the pupil concerning the stability of an instrument which also entails loss of time, and the only method of overcoming this objection is to

buy reliable instruments of high grade, because then this doubt is dispelled and a ready means of checking a test is available."

HOW TO ORDER INSTRUMENTS

The method that teachers have been compelled to adopt in most cases when ordering or requisitioning instruments has tended to thwart obtaining the type of instruments best suited for their requirements, and has therefore made it relatively easy for dealers to continue to supply grades of measuring devices wholly unsuited for school purposes.

The usual procedure in purchasing has been for the teacher to place his requisition upon the purchasing department of a Board of Education, which in turn advertises or sends out proposals for bids on the apparatus.

Special Effort Necessary if High-grade Instruments are Desired. Under such circumstances, unless special effort is made, it is difficult to obtain what is desired, because the board usually cannot (if we are correctly informed) specify any one special make of apparatus to the exclusion of other makes, providing other makes are of equal grade.

In other words, if the teacher has failed to impress upon the board that he desires a Weston instrument, or one of equal quality, the board would probably merely ask for a quotation on an ammeter or voltmeter of some specific range, and it would then be very unlikely to receive bids on any other types of instruments except those which were of the greatest advantage to the dealers to sell.

This condition of affairs has done more to encourage the sale of inferior instruments to the schools than any other, but it has been strongly augmented because in many cases teachers had not appreciated the importance of studying the differences in instruments, and probably assumed that the board was providing them with a satisfactory type.

It is relatively simple to obtain instruments that are the same in appearance, construction, accuracy and durability as those used in practical commercial work.

All that is necessary is for a teacher to become convinced of the advantage to himself and his pupils in securing dependable instruments and then to make a slight additional effort when

placing his order by carefully specifying what he wants and rejecting anything that fails to come up to the requirements.

How to Specify. Suppose a teacher wants a Weston portable voltmeter of three ranges of 150, 15 and 3 volts. He will then request the Board of Education to obtain for him:

"One Weston voltmeter, model 45, described on p. 21 of Weston Bulletin No. 501. Ranges 150–15 and 3 volts.

"A Weston instrument is specially preferred, and no other type will be considered or accepted unless it can be conclusively proven, instead of merely alleged, that it is equal in all respects to the Weston."

We will cheerfully place catalogs at the disposal of any teacher, and if our literature is not already on file in every Board of Education, it will be sent immediately upon request.

Have a Weston Catalog Available. When you desire an instrument, always send for or consult a Weston Catalog, Bulletin, or Monograph instead of looking for instruments in the ordinary school-supply dealers' catalog, but after you have received the Weston catalog, it will prove of great interest to compare the Weston and dealers' types and prices.

AFTERTHOUGHTS

While all teachers who have had experience in the use of Weston instruments will heartily testify to their exceptional quality, there still prevails among many teachers the impression that they are too good for general student service, even though it is stated that they are imperatively needed in the High School laboratory for testing other instruments or apparatus.

In reply to this contention we repeat that Weston instruments may be now purchased which range in list price from $10.50 upward, depending on the type and scales selected;

That they are accurate, exceptionally durable and generally serviceable;

That they are as easy to understand and use as other instruments;

That they are identical with instruments that will be used by the majority of students after graduation;

That they impart a knowledge of the true value of electrical measurement; and

That they are infinitely better for all laboratory purposes than instruments of any other manufacture.

If these facts are carefully considered and investigated, we are certain that the impression referred to will be dispelled, and that the marked advantage of using high-grade instruments for every student purpose will become more universally appreciated.

DEPARTMENT OF EDUCATION
THE CITY OF NEW YORK

THE STUYVESANT HIGH SCHOOL
345 EAST 15TH STREET
ERNEST R. VON NARDROFF, PRINCIPAL

NEW YORK CITY, Jan. 13, 1913.

Weston Electrical Instrument Co.,
Newark,
New Jersey.

Gentlemen:-

I am very much interested in your new line of miniature precision instruments, as they seem to me very desirable for school laboratories, on account of their accuracy, size, open character of scale and low price. The two and three range instruments and the volt-ammeters are particularly suitable.

We have been using your ammeters, voltmeters and wattmeters for over five years in our courses in Physics and Applied Electricity, and have found them extremely satisfactory in every respect. We have a number of instruments of other makes, but we do not find any of them equal to Weston instruments in accuracy, in following fluctuations of current or in damping. For several years we have confined our purchases to Weston instruments, as we have satisfied ourselves of their superiority. Both beginners and advanced students in the High School and in the Evening Trade School use the instruments. In spite of this hard usage, the instruments have maintained their accuracy, and have required no repairs, except when excessive currents have been applied.

As we believe in starting our students with commercial voltmeters and ammeters, rather than tangent galvanometers or other "school" instruments, we consider it very desirable that they should become familiar with the standard make of electrical measuring instruments, which they will use in their later professional work.

Hoping that a large number of your instruments may be placed in school and college laboratories, I remain,

Very truly yours,
Raymond B. Brownlee.
Chairman, Department of Physics and Elementary Engineering.

RRY F. KELLER, PH. D.
HEAD OF THE DEPARTMENT, AND PROFESSOR OF CHEMISTRY
CAR C. S. CARTER, B. S.
PROFESSOR OF MINERALOGY AND GEOLOGY
NJ. F. LACY, A. M., B. S.
PROFESSOR OF PHYSICS
ILIP MAAS
PROFESSOR OF CHEMISTRY
OMAS M. LIGHTFOOT, M. S., PH. D.
PROFESSOR OF BIOLOGY
WARD H. LANDIS, B. S. IN E. E.
PROFESSOR OF PHYSICS
WARD E. WILDMAN, M. S.
PROFESSOR OF BIOLOGY

CENTRAL HIGH SCHOOL

DEPARTMENT OF SCIENCE

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ASSISTANT PROFESSOR OF BIOLOGY
J. HOWARD GRAHAM, B. S.
ASSISTANT PROFESSOR OF CHEMISTRY
CLAUDE B. HAGY, C. E.
ASSISTANT PROFESSOR OF PHYSICS
ELMER B ULRICH, PH. D.
ASSISTANT PROFESSOR OF BIOLOGY
JAMES K. COYNE, B. S.
INSTRUCTOR IN CHEMISTRY
J. OSBORNE HOPWOOD, M. S.
INSTRUCTOR IN SCIENCE
LLOYD M. KNOLL, A. M.
INSTRUCTOR IN PHYSICS

PHILADELPHIA, Jan. 11, 1913.

Mr. Caxton Brown,
Secretary of Weston Elec. Inst. Co.

Dear Sir:-

Your Mr. Gilbert recently consulted me respecting our experience with Weston Instruments at this school. It gives me great pleasure to state that we have had these instruments in use here for fourteen years and find them admirably adapted for the work for which they are designed. We believe strongly in the substitution of voltmeters and ammeters wherever possible in the place of galvanometers and we are much gratified at the new types Model 280 which are within the means of most high schools. The accuracy of these instruments is remarkable.

Of course we do not recommend placing a standard instrument in the hands of inexperienced students as an instrument of such exactitude is not required by them. But we do find that several standard instruments are desirable for use with experienced students in testing instruments of lower grade.

If you purpose in entering the field to supply high schools to a larger degree than heretofore you must expect to contend with a difficulty with which you may be already familiar, namely, the lack of discrimination amongst many of those who are purchasers. Last year I secured an instrument from a firm in the West a galvanometer guaranteed as of a certain sensitivity. As is not often the case in many high schools it was tested immediately upon arrival and found to fall far below specifications. When I entered complaint with the supply company the president replied expressing surprise and stating that no such complaint had ever been entered before against the type of instrument supplied me. I regard the statement of the president as indicating that most high schools accept the instruments supplied them without any careful tests. With those who do not discriminate it is often difficult to compete against manufacturers who put out apparatus of inferior grade.

At this school we subject all instruments to the severest tests both as to accuracy and as to wear, and we have found your instruments to be of the highest quality of their respective types - a verdict in which all who do likewise will, I am sure, concur.

Very truly yours,

Edward H. Landis

MECHANIC ARTS HIGH SCHOOL
BELVIDERE AND DALTON STREETS
BOSTON
TELEPHONE CONNECTION

CHARLES W. PARMENTER
HEAD MASTER
RESIDENCE, 80 UPLAND ROAD
NORTH CAMBRIDGE
TELEPHONE CONNECTION

January 8, 1913.

File No.
Date
JAN 10 1913
RECEIVED
Ack.

Mr. George H. Moseman,
176 Federal St.,
Boston, Mass.

Dear Sir:

In the Mechanic Arts High School there are in constant use for driving ventilating apparatus and the machinery in the mechanical departments ten motors of 10 to 15 H.P., and about a dozen others ranging from 1 to 5 H.P., together with duplicate generating sets to furnish current for these motors and for lighting the entire plant which accommodates 1400 boys. The school is supplied with a complete set of Weston high grade instruments for testing these generators and motors and for laboratory use. There are also in use in the physical laboratory a number of lower cost Weston instruments. All of these instruments have been found to be highly satisfactory, and I take great pleasure in endorsing them.

It is not worth while to carry on quantitative electrical work in a high school, unless fairly accurate apparatus can be supplied. Standard instruments by which others may be calibrated are indispensable.

Very truly yours,

C. W. Parmenter

Electrical Engineering Department
FACULTY OF APPLIED SCIENCE AND ENGINEERING
UNIVERSITY OF TORONTO
TORONTO, CANADA

TORONTO, Dec.31, 1912.

Fac No.
Ord No
JAN -2 1913
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Weston Electrical Instrument Co.,
Newark, N. J., U. S. A.

Dear Sir, Attention of Mr. Caxton Brown

I have been much interested in the A.I.E.E. papers and discussions of the last year on meters, especially in so far as they related to heavy versus light-weight movements. An experience of last week settled me solidly on the side of the light-weight movement.

Several Weston meters were being taken to a factory to make certain tests. I was making the trip in an automobile of the "test car" variety, and had a reckless driver who made the most of a rough frozen clay road. To save the meters from shocks I had three of them in my arms, and the fourth - Model 155, No.7350, 10-ampere meter - jammed between my knee and a deep cushion at the outer end of the seat. One rut which that driver did not miss nearly sent us out of the car, and momentarily released my knee-grip on the Model 155 ammeter, with the result that it bounced to the floor of the car, then on to the frozen road where it fell into the rut in time for the rear tire to go over it. As the tire dropped over the meter, the box apparently slipped backwards, for it was sent spinning a few feet from where it fell. The force exerted in starting that spinning movement was sufficient to tear some small pieces out of the bottom of the meter box as it was forced to slide rearwards on the frozen ground.

When picked up the dirt on the box showed plainly that the tire went over the face of the meter across the name plate and away from the glass. The glass was not broken, which speaks well for the rigidity of the box, and the good fortune of the glass in missing contact with the ground. The pointer tip was bent about 15° from its normal radial setting. The pointer was over the scale 3/4" off zero. The pointer was apparently fairly free, but would not return exactly to its new zero setting.

That night I broke the seals and opened the meter to have a look at the wreckage before ordering a new meter. I found the trussed pointer uninjured excepting the bent tip which was easily straightened. The damping vanes were not injured or bent out of position. The rear counter-balance arm was slightly bent from shock throwing balance slightly out with the pointer set vertically. This was easy to correct. The jewels and pivots were uninjured. The shaft was not bent. The shock had bent the hair spring severely where fastened to the zero adjusting arm, which explained the off-zero setting of the pointer, and the friction, for the upper pivot was bearing hard against the side of the upper jewel cup. After bending the spring so as to make the upper pivot float in the jewel with the meter levelled, it was found that the movement was perfectly free, and its calibration practically unchanged.

How is that for a light-weight Weston movement in which all the material that is used is scientifically chosen and located to yield results?

Very truly yours,

H. W. Price.

January 8, 1913.

The Weston Electrical Instrument Co.,
Waverly Park, U. S.

Dear Sirs:

We have had in use a portable milammeter and a voltmeter of your make during the past 17 years. We also have four Eclipse switchboard instruments which were purchased about three years ago.

We have used these instruments for class work in Physics, as well as in Advanced Electricity, and find them reliable and altogether satisfactory. They serve us as standards for testing our other instruments and apparatus.

Yours very truly,

J. Y. PARCE,
Instructor in Machine Work and Electricity,
Denver Manual Training High School.

January 7, 1913.

Mr. F. E. Gilbert,
Philadelphia, Pa.

Dear Sir:

Yours of the 4th instant received. I am a member of the committee you mention.

In the Physics Department of the High and Normal Training Schools (seven in all) in Washington City we have over forty (40) Weston Electrical Measuring Instuments. The number of different students using them exceeded seven hundred (700) students. These students were enrolled in every year of our four (4) years' course. I think Weston Instruments were first used by us about four (4) years ago. None of them have been seriously injured. Needles have been bent and other minor injuries have been done to the instruments. (As a matter of experience I never allow an external shunt instrument to be used by a beginner.) I am well satisfied with my experiment in placing them in the hands of students.

Send us any advertisements you get out, especially of the almanac or calendar type.

Yours truly,

WM. A. HEDRICK,
Head of the Dept. of Physics.

ELEMENTARY ELECTRICAL TESTING

A COMPILATION, PRESENTING SOME OF THE MOST RECENT OPINIONS AND METHODS OF PROGRESSIVE PHYSICS INSTRUCTORS

MONOGRAPH B-2

SECOND EDITION, AUGUST, 1914

ISSUED FOR

SCIENCE TEACHERS IN EDUCATIONAL INSTITUTIONS

"Those who from a love of truth would pursue it for its own sake are so overworked with the drudgery of elementary teaching, and so poorly supplied with the implements of investigation, that it is not surprising that science has made comparatively *little* advance among us, but that, under existing conditions, it should have made so much."—JOSEPH HENRY.

(*Extract from a letter to the Committee of Arrangements of the Farewell Banquet to* Prof. TYNDALL, *Delmonico's, New York, 1873.*)

WESTON ELECTRICAL INSTRUMENT CO.

NEWARK, N. J.

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ARGUMENT

THIS monograph is prepared as evidence of our belief in the new movement to make education more practical. The Weston Electrical Instrument Company is convinced that the public high school instructors desire to use pedagogic material drawn from real life and prefer to perform laboratory experiments which teach the fundamentals of science as far as possible with commercial equipment, such as the student will later use or see used, and with which he will later be expected to be familiar.

Assured that teachers want to know what technical men in the industries believe to be fundamental, we have prepared brief suggestions relating to the preparation of a course in electrical measurements. Representatives of our house have been observing the work of schools for several years. In issuing this monograph, we have consulted authorities on pedagogics. We have also received the advice of school men and have then printed such matter as appealed to our judgment.

Some of the suggestions offered may be beyond the present scope of high school physics, although extremely elementary from our standpoint.

Since this is neither presented as a text book, nor offered as a complete outline of a course of study, but merely contains material offered for consideration, it is probable that, as this movement progresses, exercises which are at present too advanced may later be acceptable and even necessary.

Exercises credited to authors of text books have in some instances been abbreviated but not altered in detail, even though in our judgment and in the judgment of members of the Joint Committee changes could well be made. We have, however, appended our opinions when we differed considerably with the author, or believed suggestions were appropriate.

We hereby express our thanks to the authors and publishers who permitted us to quote from their works.

We wish to acknowledge our indebtedness to the members of the Joint Committee on Physics who have advised us in both the general plan of the monograph and in the selection and arrangement of the material. All of our suggestions which were adjudged by the committee members to be impracticable under existing conditions pertaining to schools have been eliminated. However, every effort has been made to make this monograph represent the judgment of our Staff, rather than that of the educators consulted.

WESTON ELECTRICAL INSTRUMENT COMPANY.

THE EXTENSIVE USE OF ELECTRICAL ENERGY IN NUMEROUS INDUSTRIES

In re-outlining the course of study in high schools, due consideration should be given to the fact that changes in the relative importance of certain industries have recently taken place, and that these changes affect both the home and the civic life of our people in various communities.

The new census gives figures to support the statement that electrical industries are economically more important than the chemical industries in point of the number of wage-earners employed and in the value of the product manufactured each year.

It is estimated that ten billion dollars are now invested in electrical industries. About one-fourth of this represents the capital invested in power developments of a semi-public nature.

The educational significance of these facts is two-fold:

First. In emphasizing that *more attention must be given by instructors to the industrial applications of electricity, and to physics generally.*

Second. In the direct answer which they give to the question as to what constitutes *practical* ideas from the business man's point of view. We will elaborate this point. The greater portion of this tremendous investment is dependent upon the maintenance of circuits having a pressure of 110 volts or over. Accordingly the first things that students should learn are the facts concerning these circuits. For developing means of teaching these and other facts the country is dependent upon its educators. It is from teachers only that the student may obtain comprehensive ideas relating to the materials, arrangement and methods of distribution of electrical circuits. Just as the water and gas mains, with their innumerable outlets and ramifications, supply a city with two necessities, the electrical conductors give us access to an agent—a source of energy—which has become more necessary to us than gas, and in frequent instances is

almost as indispensable as water. And this agent, this source of energy, is an electric *current.*

It seems logical and proper, therefore, that a course in elementary electrical measurements should begin with the consideration of the subject from the standpoint of current.

CURRENT

The following exercise, published in the Manual of Fuller and Brownlee,* Experiment 77, is here given in part as an illustration of a method of teaching current distribution.

EXPERIMENT I

RESISTANCE AND CURRENT IN A DIVIDED CIRCUIT

Object. To compare (*a*) the currents in the branches of a divided circuit with the resistance of those branches; (*b*) the total resistance with the resistance of the branches.

Apparatus. Lamp board like that shown in Fig. 1; 32-candle-power lamps to fill board; 3 ammeters; voltmeter, with connecting wires; connections to 110 volts D.C. circuit.

Experimental. Proper connections for a circuit of two branches, like that shown in Fig. 1, are to be made. The resistance in each branch of the circuit consists of an equal number of similar incandescent lamps, connected in parallel. The ammeters are so connected that the total current through both branches can be read and also the individual current in each branch. The terminals of a voltmeter, which is not shown, are to be connected to the terminals of any portion of the circuit whose resistance is desired.

All the lamps on both sides are to be turned on and reading of each ammeter recorded. The voltmeter is then connected in succession to the terminals of each branch circuit and to the terminals of the combined circuit and the readings obtained recorded in tabular form.

* Published by Allyn & Bacon, Boston.

All the lamps but one on one branch are then turned out, leaving all the lamps in the other branch of the circuit burning. Readings of the voltmeter and ammeters are taken and recorded as before. Make the following additional combinations in the two branches and record the results: 2 lamps and 3 lamps; 2 lamps and 4 lamps; 2 lamps and 5 lamps.

A simple diagram of connections should be made, and a brief description of the method of making the tests should be given. From the readings of the instruments the resistance of each branch and the resistance of the entire circuit should be calculated for each case by the application of Ohm's Law.

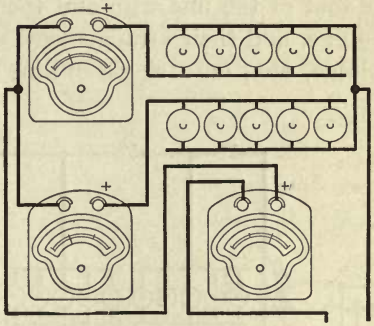


FIG. 1.—Lamp Board, Ammeters and Connections.

Instruments used are Model 280 Weston Ammeters, Range 10 Amperes.

Discussion. Does increasing the number of lamps in parallel in a circuit increase or decrease the resistance of the circuit?

EXPERIMENT II

THE DISTRIBUTION OF CURRENT, VOLTAGE AND POWER IN A MODEL LIGHTING CIRCUIT. TWO-WIRE SYSTEM.*

Apparatus. Model lighting circuit; 110-volt supply; ammeter; two voltmeters; rule; fuses.

Method. The line wires, Fig. 2, are composed of a high-resistance wire. The taps from the line wires (except at Group *V*) are of heavy copper wire. This furnishes a model lighting circuit, which has a measureable loss in voltage and power in the line wires, as would be the case for an actual incandescent

* From The Loose Leaf Manual, Timbie's Electrical Measurements. Published by John Wiley & Sons, Inc.

lighting circuit. The openings, 1, 2, 3, etc., are made so that an ammeter can easily be inserted to measure the current in all parts of the system.

Get directions from an instructor regarding the ohms per mil-foot of the line wire and the number of lamps to be used in the line, and their arrangement. Record all readings of current, voltage, etc., on a single outline diagram of the line, similar to Fig. 2.

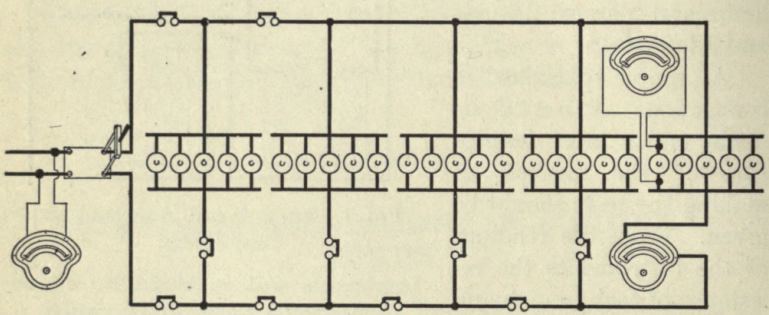


DIAGRAM OF THE MODEL OF A LIGHTING CIRCUIT, USED IN PRATT INSTITUTE, BROOKLYN, N. Y.

FIG. 2.—The Instruments Shown are Weston Model 267, Voltmeters and Ammeters.

Data and Results. The switch at the end of the line is to be regarded as the source of power. Measure the voltage at this switch and the current in each section of the line *at this voltage.*

Measure with a micrometer caliper the size of the line wire, also with a rule the distance from the switch to the first group of lamps, and the distance from each group to the next succeeding group. (Measure in each case to the point on the mains at which the short leads from the lamps are attached. The resistance of the short copper leads to the lamps may be neglected.)

From its length and mil-foot resistance, compute the resistance of each section of the line. Compute the "drop" over each section, and the voltage at each group of lamps. Check your computed voltage by comparison with voltmeter readings taken across the lamps. *As the supply voltage may fluctuate, one voltmeter should be kept con-*

nected across the supply switch, and the voltage at the lamps should be read from a second voltmeter when voltage at the switch is at the proper value.

From your data determine also:

1. The watts delivered at the power switch.
2. The watts expended in each section of the feed wires.
3. The watts expended in each group of lamps.
4. The total watts supplied to the lamps, and the total line loss.
5. The " efficiency " of the line—i.e., the per cent of the total power supplied which is delivered to the lamps.
6. The resistance of each group of lamps.
7. The average hot resistance of a single lamp.

Show all computations in your report.

From your data determine also:

1. The watts delivered at the binding post terminals.
2. The watts expended in each section of the feed wire.
3. The watts expended in each group of lamps.
4. The total watts supplied to the lamps and the total line loss.
5. The " efficiency " of the line, i.e., the percentage of the total power supplied which is delivered to the lamps.
6. The resistance of each group of lamps, and the average hot resistance of each lamp.

If conditions permit, we would suggest that a teacher would better have small groups of students use a part of the actual lighting circuit in the school, in place of a model, and follow the directions given in the experiments as far as possible.

This plan is suggested by the letter on page 26 of our Monograph B–1, written by Mr. C. W. Parmenter, Head Master of the Mechanics Arts High School, Boston. The plan is also used by Prof. H. H. Higbie of the Wentworth Institute, Boston, Mass.

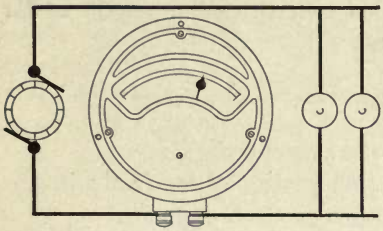


FIG. 3.—Connection for Ammeter with Self-contained Shunt.

Instrument shown is a Weston Model 24.

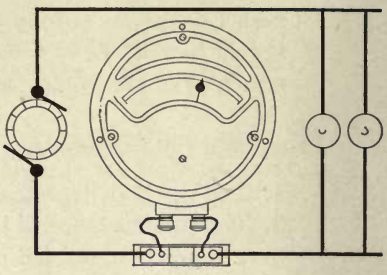


FIG. 4.—Connection for Ammeter with Detachable Shunt.

Instrument shown is a Weston Model 24.

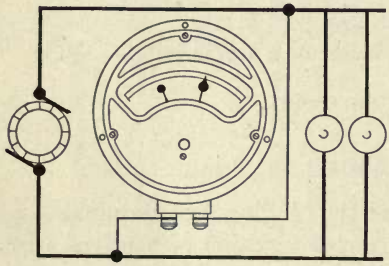


FIG. 5.—Connection for Voltmeter.

Instrument shown is a Weston Model 24.

CONNECTIONS FOR VOLTMETERS AND AMMETERS

The student's attention should be called to the fact that an ammeter should always be connected in series with the line, whereas a voltmeter should be connected across the line. See Figures 3, 4 and 5.

EXPERIMENT III

THE FALL OF POTENTIAL ALONG A CONDUCTOR

The nature of a divided circuit and the current in it may have been called the primary idea in the preceding experiments, but they served as well as means of discussing the theory that it is *pressure* which actually forces the current through.

Schools have for a long time given an exercise showing the "Fall of Potential along a Conductor," and it merely remains for the teacher to give this exercise a more practical atmosphere to have it continue to be one of the strongest on the list.*

* See Experiment No. 29, Laboratory Manual in Physics. Wauchope, Scott, Foresman & Co., New York and Chicago.

Apparatus Required. Weston ammeter, range 3 amperes; Weston voltmeter, range 3 volts; 1 meter slide wire bridge; storage cell or 2 constant primary cells in series; No. 18 (B. & S. gauge) 40-mil Weston alloy wire; No. 24 (B. & S. gauge) 20 mil-Weston alloy wire.

A length of 40-mil alloy wire is stretched over the meter rod and securely clamped. The resistance of 40-mil alloy wire is approximately 0.50 ohm per meter.

One storage cell, with the ammeter in series, is connected with the stretched wire, an extra piece about $\frac{1}{2}$ meter long is included in the circuit and its length is regulated until the current flowing is 3.00 amperes. See Fig. 6.

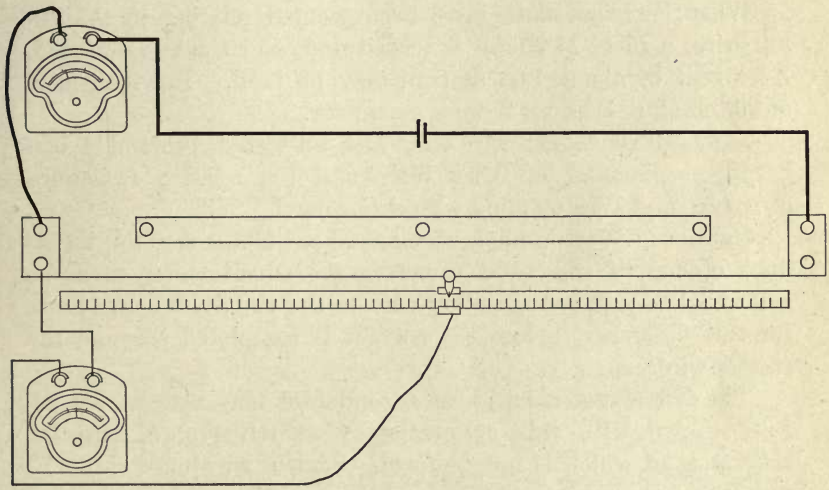


FIG. 6.—Ammeter is a Weston Model 280 Range 3 Amperes. Voltmeter is a Model 280 Range 3 Volts, Zero in Center.

The 3-volt range of the voltmeter is also connected as shown and primarily the drop over the entire length of wire is found

The resistance of 1 meter of wire is then determined by the formula $R = \frac{E}{I}$.

It must be borne in mind, however, that this is not a " zero " method, and theoretically, at least, is not correct. That is to say, since current is necessarily flowing through the voltmeter

when in use, the instrument therefore forms part of a divided circuit by shunting the resistance wire.

If an improperly constructed voltmeter of low resistance is employed, its introduction will affect the indications of the ammeter by materially reducing the total resistance of the circuit, and its own indications will be erratic and disproportionate when different lengths of the resistance wire are being tested.

Weston voltmeters have sufficiently high resistances to prevent the irregularities referred to, but nevertheless the best method for determining the total resistance of the wire is to ascertain the drop over definite lengths of the wire, such for instance as 10 centimeters, tabulate the results, obtain a mean value and determine the total resistance by direct proportion.

When sufficient data have been secured relating to the 40-mil wire, a piece of 20-mil is substituted, and the test repeated. A current of about 1.00 ampere may be used. The resistance of 20-mil alloy is about 2 ohms per meter.

A length of copper wire may also be tested, preferably one having a diameter of 0.020 inch, and the relative resistance of copper and Weston alloy wire determined.

Caution: Weston alloy wire has about 23.5 times the resistance of copper wire, and therefore the experimenter must be cautioned to add enough alloy wire to the circuit to compensate for this difference, before the current is completed through the copper wire.

The fall of potential along a conductor may also be beautifully shown with this apparatus by substituting a wire the resistance of which is not uniform. Such a wire may easily be prepared by scraping or filing a resistance wire at irregular distances while stretched, and by coating it with a little solder here and there, afterwards smoothing with emery paper.

The two voltmeter leads are then held, one in each hand, so as to span a section of the wire, and the deflection is noted and compared with the results obtained with other sections of the same length.

EXPERIMENT IV

THE FALL OF POTENTIAL IN A LAMP BANK *

Question. What is meant by "Fall of Potential"?

Apparatus. Source of 110-volt current; three electric lamps; voltmeter.

Directions. Pass the current through the three lamps connected in series as shown in the diagram. It requires electrical

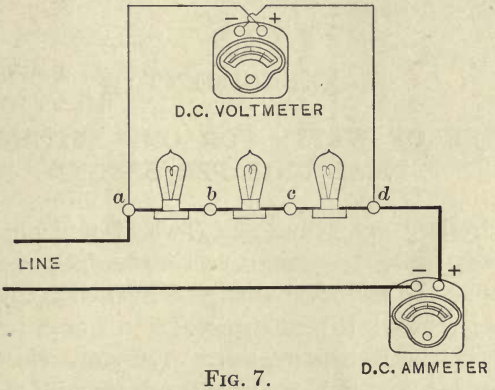


FIG. 7.

Instruments used are a Model 280 Weston Ammeter, Range 3 Amperes, and a Model 280 Weston Voltmeter, Range 120 Volts.

pressure to force the current through the lamps. This pressure is measured by the voltmeter. Connect the terminals of the voltmeter to *a* and *d* to obtain the volts pressure required to drive the current through all three lamps. In like manner find the difference of electrical pressure between *a* and *c* for two lamps, and between *a* and *b* for one lamp.

Results. Volts pressure required for three lamps =
Volts pressure required for two lamps =
Volts pressure required for one lamp =

Discussion. Potential is only another expression for electrical pressure. Difference of potential means difference of electrical

* From "Manual in Physics," by Joseph A. Wauchope.

pressure, and fall of potential means fall of electrical pressure. A voltmeter is used to measure the potential difference between any two points in an electrical circuit, just as pressure gauges are used between any two points of a water pipe. The further away from the pumping station the greater the fall of pressure of the water in pounds per square inch, due to the resistance of the pipes.

So the further the electric current goes in a conductor the greater the fall of potential in volts, due to the electrical resistance of the conductor. The greater the resistance the greater the fall of potential. Do the lamps used in this experiment all have the same amount of resistance? Why do not the lamps give light in this experiment?*

EXPERIMENT V

NUMBER OF WATTS FOR ONE BRITISH THERMAL UNIT PER SECOND

In "Physics," by Mann and Twiss,† the following exercise is suggested, which has long been successfully used in schools to teach that the electrical energy delivered to an incandescent light is transformed into heat energy.

An ordinary 16-candle-power, 110-volt, electric lamp is placed in a jar containing a measured amount of water and a thermometer (Fig. 8). The heat from the lamp warms the water. If the jar contains 2 pounds (1 quart) of water and if a Fahrenheit thermometer is used, the temperature of the water rises about $1\frac{1}{2}°$ F. per minute—i.e., the water is heated at the rate of 3 B.T.U. a minute.

* In the "Physical Laboratory Manual," by Ball, Hauptman and Bateman, issued by the Cooper Union Supply Store, New York, a different method is given, which consists in employing a lamp bank, a gold-leaf electroscope, and a Weston voltmeter.

They call attention to the fact that the leaves of the electroscope will diverge less and less as the knob of the electroscope is connected at the points of decreasing potential, and then add:

"Now use a Weston voltmeter in place of the electroscope and note the readings of the voltmeter for the same points. Note how much more accurately the potential difference can be estimated by means of the voltmeter than by means of the electroscope."

† Scott, Foresman & Co., Publishers, New York and Chicago.

A voltmeter and an ammeter measure the electric power supplied to the lamp. If the voltmeter reads 110 volts, and the ammeter reads $\frac{1}{2}$ ampere, the power supplied is 110 (volts) $\times \frac{1}{2}$ (ampere) = 55 watts. Hence, roughly, 55 watts = 3 B.T.U. per minute; or 1100 watts = 1 B.T.U. per second.

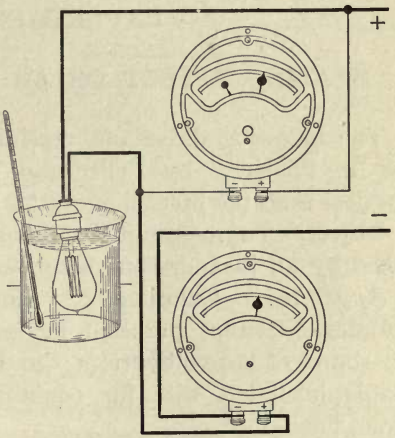


FIG. 8.

Instruments used are a Weston Model 24 Voltmeter and Ammeter.

The first determination of this relation was made more accurately by the same Joule who made the first determination of the relation between the B.T.U. and the foot-pound. The apparatus (Fig. 9) does not differ in principle from that used by Joule. A coil of platinum wire is placed in a jar containing a measured quantity of water and a thermometer. A voltmeter and an ammeter, arranged as shown in Fig. 8, measure the number of watts of electric power used in heating the coil. The number of B.T.U. given up by the coil to the water in a certain time is obtained by multiplying the number of pounds of water in the jar by the number of degrees F. rise in temperature.

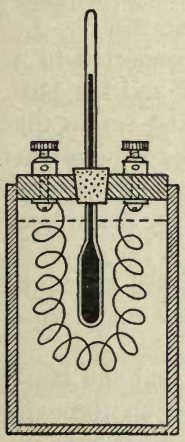


FIG. 9.

Joule's experiments have been repeated many times by many other scientists, using different current strengths and different kinds of coils. The results of all of these experiments show that there is a constant ratio between the heat unit and the unit of electric power; and they give the accurate value of this ratio as

1055 watts = 1 B.T.U. per second.

4.2 watts = 1 gram-calorie per second.

The above exercise, as described, deals merely with the rela-

tion that the power units (watts and B.T.U. per second) bear to each other.

EXPERIMENT VI

HEATING EFFECT OF AN ELECTRIC CURRENT

The following directions, reprinted from "Laboratory Exercises in Physics," by Fuller and Brownlee, seem to be more practical than the preceding one.*

Object. To measure the number of calories of heat furnished by an incandescent lamp and to calculate the cost.

Apparatus: Calorimeter; thermometer; 16-candle-power incandescent lamp; porcelain keyless socket; voltmeter; ammeter; source of 110-volt current; graduate, or balance and weights; flexible insulated wire for connections; watch or clock with second hand.

By allowing a lamp to heat a known weight of water for a measured time, we may find the calories per second furnished by the lamp. If we know the current and voltage of the lamp, we may estimate the heat liberated per kilowatt-hour. Although *all the heat* liberated by the lamp will not be measured in this experiment, yet the efficiency of the lamp as a heater, as used here, compares favorably with regular heating apparatus.

Experimental. A porcelain keyless socket is connected to a 110-volt line with an ammeter between the socket and the 110-volt terminals (Fig. 10). A voltmeter is connected across the terminals of the socket. A lamp is then screwed into the socket and the switch closed in the circuit to make sure that the connections are correct and that the instruments read in the proper direction. The lamp is then turned off till needed.

Into a nickel-plated brass calorimeter is placed 250 grams of water at a temperature six or seven degrees below room temperature.

This is stirred thoroughly with a thermometer and the temperature noted; immediately the current is turned on through the lamp, which is inserted in the calorimeter, the exact time in minutes and seconds being noted.

* See also Experiment 92 in "Experimental Physics," by Smith, Tower and Turton. Ginn & Co.

The time and the temperature of the water are recorded in the tabular form near the top of the left-hand page, the voltmeter and ammeter also being noted and recorded. The lamp should be immersed until the tip rests on the bottom of the calorimeter, and the thermometer should stand in the calorimeter beside the lamp. For the next five minutes the lamp burns inverted in the water. By moving the lamp up and down in the water, never raising it more than a quarter of an inch from the bottom, the water can be kept stirred and so of equal temperature throughout.

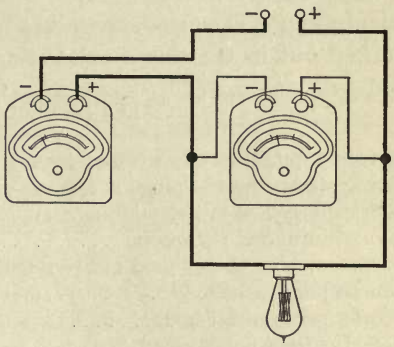


FIG. 10.

Instruments used are a Model 280 Weston Ammeter, Range 3 Amperes, and a Model 280 Weston Voltmeter, Range 120 Volts.

The calorimeter should not be handled during the experiment. The voltmeter and ammeter should be frequently observed, and if there is any variation, the average reading for the whole time should be the one recorded and used.

When the lamp has been in the water exactly five minutes, take it out promptly, stir the water vigorously with the thermometer, and read and record the temperature.

Using fresh quantities of water, repeat the test twice. The water equivalent of the calorimeter should be obtained from the instructor.

Make a sectional drawing of the calorimeter with lamp and thermometer in place and with the connections of the instrument shown.

A brief description of the method of the experiment should accompany the drawing.

From the weight of the water, with the water equivalent of the calorimeter added, and the change of temperature, the number of calories furnished in five minutes can be calculated. The number of watt-seconds is found by multiplying volts, amperes, and seconds together. From these two results calculate the

calories per watt-second and per kilowatt-hour. As the time and the weight of water are the same in all three tests, the averages of temperature changes, volts, and amperes will be used in the calculation. The problem called for in the conclusion should be worked out in the note-book, using the local rate for electricity.

CALCULATED RESULTS

Corrected weight of water (water+water equivalent of calorimeter)	g.
Average temperature change in five minutes	c.
Calories furnished in five minutes	cal.
Calories furnished per second	cal.
Watt-seconds of energy used in five minutes	w. s.
Calories per watt-second	
Calories per kilowatt-hour	
Cost of current per kilowatt-hour	c.

Discussion. Explain any way in which heat generated by the lamp may escape without being measured in this experiment.

Conclusion. At the price of . . . ¢ per kilowatt-hour, the cost of raising 4 liters of water from 15 to 100° C. will be . . . ¢ if an electric heater of the same efficiency as the lamp is employed.

POWER

A series of exercises designed to emphasize the difference between work and power as measured in electrical units (e.g., watt-hour and kilowatt) is commercially of primary importance.

In "A High School Course in Physics," by Gorton,* will be found the following terse and lucid definition:

"Power of an Electric Current. Since *power* refers to the rate at which work is done or energy expended, it may be found by simply dividing the total energy expended by the time. In an electric circuit, therefore, the power is measured by the product of the potential difference and the current strength; or, *Power* (watts) = volts × amperes."

* D. Appleton & Company, Publishers. New York and Chicago.

EXPERIMENT VII

EFFICIENCY TEST OF AN ELECTRIC MOTOR

There is a rapid increase in the number of school laboratories which have a small electric motor. These motors are usually of recent design, and of $\frac{1}{2}$ horse-power or over in rating.

The student who uses motors of this type is usually impressed by the fact that he is working with real commerical quantities of energy and with actual life-size machines.

A determination of the brake horse-power and efficiency of such a motor is considered an essential part of the laboratory course in many of our high schools. Such a test is very well described in " Physics," by Mann and Twiss, as follows:

" As with simple machines, water motors, and steam engines, the most important thing about electric machines is the efficiency.

" Suppose that we have bought a 110-volt motor that is built to develop two horse-power, and we wish to test its power and efficiency in order to see whether it does what is claimed for it. The voltmeter V, whose terminals are attached to those of the motor (Fig. 11), measures the $P\ D$ at the motor. It should read 110 volts. The ammeter A, placed in the power circuit in series with the machine, measures the number of amperes flowing through the motor. Suppose it reads 16 amperes. Then the power supplied to the motor (power in) is

$$110 \text{ (volts)} \times 16 \text{ (amperes)} = 1760 \text{ watts.}$$

" A brake is applied to the axle of the motor and the readings made.

" Let us suppose these readings to be as follows:

" Circumference of brake wheel, 2 feet; revolutions per minute, 360; pull on brake, 82.5 pounds. Then the power obtained from the motor is:

$$82.5\text{(lbs.)} \times 2\text{(ft.)} \times 360\text{(r.p.m.)} = 59{,}400 \text{ ft.-lbs. per min.}$$

" Dividing this by 33,000 ft.-lbs. per min. to reduce it to horse-power, we get 1.8 horse-power.

"So 1760 watts of electric power was supplied to the motor to make it do work at the rate of 1.8 horse-power. This result enables us to compare the efficiency of this motor with that of others; but it does not state what the real efficiency of this motor is, because the power in is expressed in watts, and the power out is expressed in horse-power." *

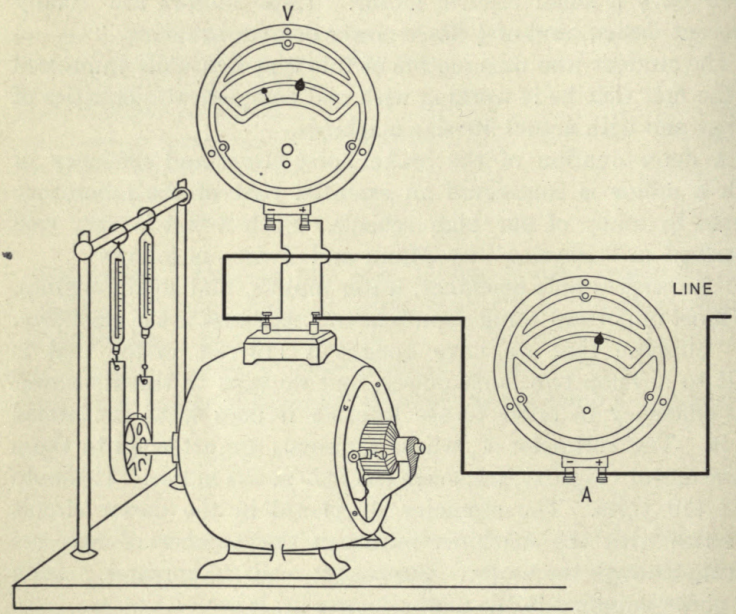


FIG. 11.

Instruments used are a Model 24 Weston Ammeter and Voltmeter. Ranges 25 Amperes and 125 Volts.

RESISTANCE

The most accessible means for measuring quantities with commercial accuracy are the ones most frequently ignored. In the measurement of resistance it is perhaps true that instructors neglect the voltmeter-ammeter method because it seems so obvious. Certainly no quicker method could be selected than

* See also Experiment 37, Wauchope's Manual in Physics. Scott, Foresman & Co. New York and Chicago.

that of placing an ammeter in series, and then connecting a voltmeter across the terminals of the conductor to be tested. Nothing else is necessary except perhaps a rheostat to regulate the amount of current.

Every student knows enough of algebra and of Ohm's law to solve for the resistance when he has taken such measurements. The student who is thus early asked to test the resistance of each phase of an induction motor, the fields of a direct-current motor, the ballast coils in an arc lamp, or any other electrical device, starts with a fair appreciation of what ordinary commercial measurements of resistance are like.

The following experiment fully describes the advantages and limitations of this method:

EXPERIMENT VIII

THE DETERMINATION OF LOW RESISTANCES BY THE AMMETER AND VOLTMETER METHOD

Apparatus Required: Weston ammeter; Weston millivoltmeter, 500 millivolt range; Weston voltmeter, 3 and 15 volts; unknown low resistance; storage battery, 3 cells, Weston alloy or carbon rheostat.

This method is identical in principle with the one by which the fall of potential along a conductor is determined. Commercially, it is constantly used for testing the resistances of bus-bars, dynamo armatures, shunts, etc.

A Weston ammeter, preferably with a detachable shunt having a standard drop, is connected in series with the resistance material to be measured, a rheostat, and a source of steady current.

Current is regulated until a suitable ammeter deflection is obtained.

If the resistance of the material to be tested cannot be determined approximately by calculation, a voltmeter should first be connected across its extremes *a* and *b* (see Fig. 12) and a preliminary test made to learn whether the potential between these points is too great to permit the use of a millivoltmeter. If this is not the case, the millivoltmeter is substituted, its deflec-

tion noted, and the resistance between a and b is found by the formula

$$X=\frac{E}{I},$$

I being the current and E the e.m.f. indicated by the millivoltmeter.

Strictly, the value obtained is not that of the resistance material only, but of the combined resistance of the material and the millivoltmeter in parallel.

To determine the resistance accurately, a more refined method must be used, as follows:

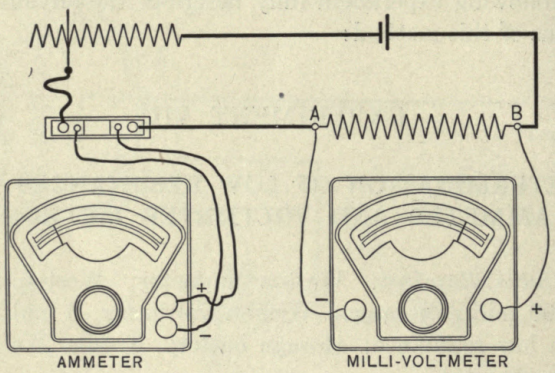


FIG. 12.

Weston Model 1, Instruments.

After the "drop" and current have been ascertained as given above, the leads of the millivoltmeter are disconnected and the resistance of the instrument (if unknown) is measured by a bridge. Then the true resistance of the material between the potential points is:

$$X=\frac{Er}{Ir-E}.$$

r = Resistance of the millivoltmeter.

Examples:

Let $0=1.4$ amperes; $E=0.056$ volt, and $r=2$ ohms; then

$$X=\frac{0.056\times 2}{(1.4\times 2)-0.056}=0.040817 \text{ ohm.}$$

If the first method were used, $X=\frac{E}{I}$ would give $X=\frac{0.056}{1.4}=0.04$, or an error of about 2 per cent.

If, however, the current were 450 amperes and the drop 0.054 volt, by $\frac{E}{I}$ we would have $\frac{0.054}{450}=0.00012$ ohm, and by the second formula $X=\frac{2\times0.054}{(450\times2)-0.054}=0.0001200072$, and the difference in the results would be negligibly small. Hence, when very low resistances are being measured and large currents are used, the simpler method is preferable.

Another variation of this method, which is useful for measuring armature resistance, etc., results from the use of a single millivoltmeter, and a known low resistor approximately equal to the unknown resistance, in place of the shunt. Then by first connecting the millivoltmeter across the resistor, the current through the circuit may be computed by Ohm's law. Next, by placing the instrument terminals across the unknown resistance, the fall of potential through it and also its resistance may be then determined. With steady current, this method is as accurate as the first one, but since it is assumed that the conditions do not change between tests, it cannot be relied upon with fluctuating current.

INSULATION

An ideal condition of affairs would be to have a perfect conductor of electricity protected by a perfect insulator. We would then always secure 100 per cent efficiency, irrespective of the length of cross-section of our conductor. But unfortunately we have neither, since all conductors have resistance and all insulators are imperfect conductors. The result is that there is always a current discharge on a line. This discharge or "leakage" is increased by the use of poor or worn insulating material and by dampness.

In all electric light and power stations, leakage is regarded as waste, involving a direct financial loss. Therefore, it is of great importance to be able to "keep up the line insulation" and to understand how to locate leaks or "grounds."

EXPERIMENT IX

THE DETERMINATION OF HIGH RESISTANCES BY THE VOLTMETER DEFLECTION METHOD

Apparatus Required: Weston direct-current voltmeter, 150-volt range; high unknown resistance; direct-current line voltage, 100 to 120 volts.

On a direct line, in order to successfully determine insulation resistance, it is necessary to use a Weston permanent magnet movable-coil type of high-resistance voltmeter, with a uniformly divided scale. The resistance of the instrument should be known.

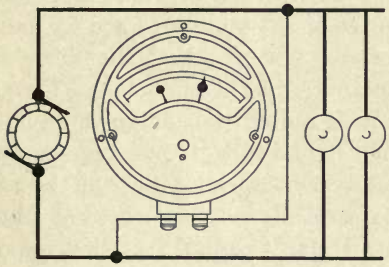


FIG. 13.

Weston Model 24 Voltmeter, Range 150 Volts.

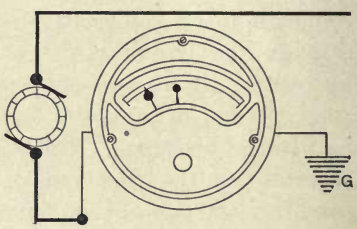


FIG. 14.

Weston Model 24 Switchboard Voltmeter, Range 150 Volts.

The normal voltage of the line is then found by connecting the voltmeter across the line, as shown in Fig. 13, and the deflection noted.

One binding post of the instrument is then grounded by connecting it with any convenient water, gas or steam pipe, and the other binding post connected directly with one of the generator terminals. The other generator terminal is connected with the line to be tested and the resultant deflection also noted. See Fig. 14.

The resistance of the line (in ohms) is then found by the formula:

$$X = \frac{S \times R}{S'} - R.$$

S = First deflection in scale divisions;
S' = Second deflection in scale divisions;
R = Instrument resistance.

Example:

$$S = 120; \qquad S' = 20; \qquad R = 15000;$$

$$X = \frac{120 \times 15000}{20} - 15000;$$

$$X = 75000.$$

The insulation resistance of a line or cable may readily be determined in this manner if it is not too high.

Sometimes, when the insulation is very poor, a fine class-room illustration can be made by grounding the line through an ammeter in series with an incandescent lamp, as shown in Fig. 15.

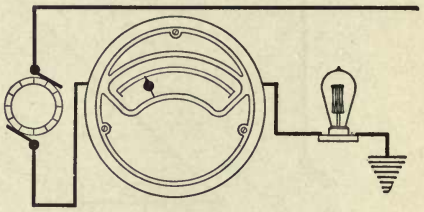


FIG. 15.

Weston Model 24 Switchboard Ammeter, Range 5 Amperes.

EXPERIMENT X

THE WHEATSTONE BRIDGE

The Wheatstone bridge remains the time-honored instrument for the highly accurate determination of resistance. In commercial testing laboratories, it is regularly used for routine and special work demanding greater precision than can readily be obtained by more rapid methods. Its use is also common for measurements in which the large currents or voltages required by other methods are either unobtainable or objectionable. As an illustration, reference might be made to its use in telegraph and telephone tests for faults and grounds. The Wheatstone bridge is operated by specially trained workers, and for educational purposes it should not be classed with voltmeters, ammeters, and wattmeters as an instrument with which every high-school graduate should be familiar.

Many teachers question the wisdom of attempting to teach beginners the principle and operation of this instrument, as much because of the indifferent success which so frequently results as because of its special character. This discussion is intended for those teachers who feel that they must attempt its use. The slide-wire form is here suggested, not only because it is already in common use, but also because it lends itself to a close correlation between the "Fall of Potential" exercises which should precede it.

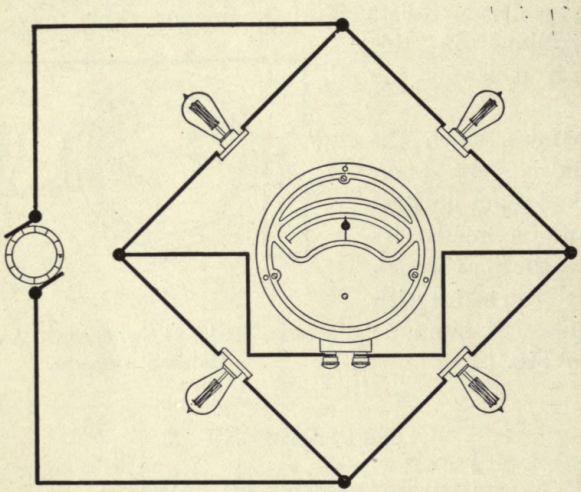


FIG. 16.

The Instrument is a Weston Model 24 Zero Center Ammeter.

Apparatus Required: Slide wire bridge; Weston student galvanometer; Weston ammeter; resistance box; resistance wire; coil of unknown resistance; one or two cells; incandescent lamps.

If four incandescent lamps are arranged in multiple series, as shown in Fig. 16, and connected in the line, they will serve excellently to demonstrate the principle of the parallelogram of forces, as exemplified by the Wheatstone bridge. Even if the rest of the exercise is omitted, this part should be given as a classroom demonstration. The instrument should preferably be a zero center ammeter.

Suitable questions would be as follows:

If an ammeter is connected (as shown), what will happen? Will it indicate, and if not, why not?

If one of the lamps is removed, what will be the result?

If a lamp of different size (resistance) is substituted, will it make any difference?

If, instead of the lamps, a parallelogram of resistance wire is constructed so that the four sides have the same resistance, and a battery and galvanometer are connected, as shown in Fig. 17, the current will split where A and B unite, pass through A and X and also through B and R, reuniting where R and X join. The four "arms" of the bridge being alike, no current will flow through the galvanometer when connected as shown. In other words, the potential at the junction of AX and BR will be the same. The battery and galvanometer may then be interchanged without affecting the balance.

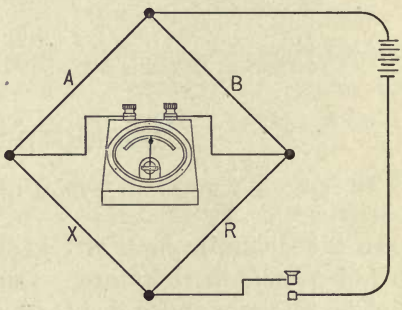


FIG. 17.

The Instrument is a Model 375 Weston Galvanometer.

To construct a practical bridge, it is only necessary to substitute for A, B, X, and R conductors of large area and negligible resistance with suitable gaps for the insertion of resistance coils and the material to be measured. See Fig. 18. If then, A and B are each 100 ohms and R is also 100 ohms, a balance is secured by adjusting X, and when no current flows through the galvanometer the resistance of X will be 100 ohms. If the resistance of X is to be determined, R is made adjustable and is varied until it equals X. The resistance of R and X, if equal to each other, may differ greatly from A and B, and an equilibrium be established, provided A and B equal each other. Finally A, B, R, and X may all differ in resistance and a balance be secured, provided a proportionality exists in their respective resistances—for instance, when

$$A=10, \quad B=100, \quad X=35 \quad \text{and} \quad R=350.$$

These conditions exist when an uneven bridge or ratio is used in making measurements.

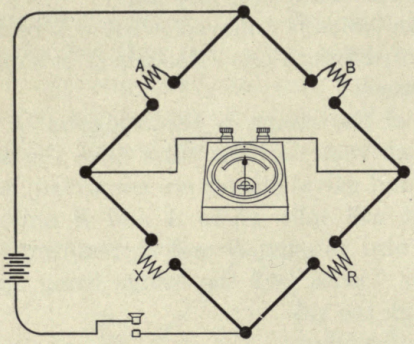


FIG. 18.

Instrument Shown is a Model 375 Weston Galvanometer.

EXPERIMENT XI

THE SLIDE-WIRE BRIDGE

In the slide-wire form of bridge *A* and *B* consist of a single wire of a uniform resistance. Contact may be made at any point on this wire and a scale is provided to determine the posi-

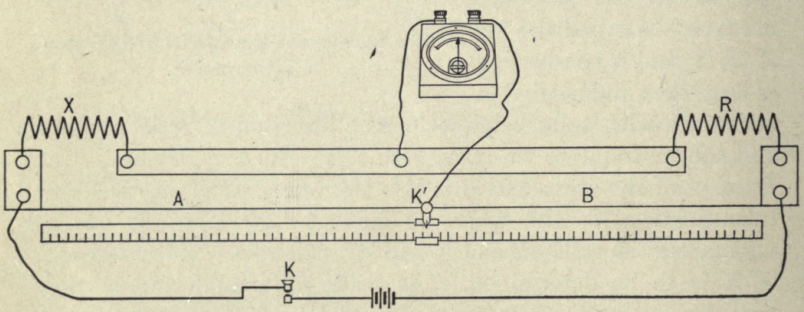


FIG. 19.

The Instrument is a Model 375 Weston Galvanometer.

tion of contact. See Fig. 19. The galvanometer is preferably connected as shown; an unknown resistance is inserted at *X* and a box of coils at *R*.

Contact keys k and k' are used to close the circuits through the battery and galvanometer.

The slide-wire contact is at first placed centrally, and an approximate balance secured by varying R. A place is then found on the slide wire where perfect balance is secured.

Since the scale is divided into a thousand parts, the resistance of X can be closely determined by simple proportion.

EXPERIMENT XII

THE EFFECT OF TEMPERATURE ON THE RESISTANCE OF A LAMP FILAMENT *

Apparatus: 110-volt direct current; series lamp resistance or any suitable adjustable resistance; switch with 6-ampere fuses; ammeter; voltmeter; lamps to be tested. (These should be of several types.)

The difference between the resistance of an incandescent lamp filament when the switch to power is first closed and the resistance of the same filament an instant later when the filament has been raised to its normal operating temperature, is a matter of considerable commercial importance. With the old type carbon filaments, where the temperature effect is to give a smaller initial current, the phenomenon could be safely allowed to adjust itself. With the newer metallic filament lamps in which the first rush of current may be much greater than the normal operating current, some protection to the line, when the power switch is first closed, is frequently necessary where large groups of lamps are being supplied. That the character and extent of this temperature effect vary with various types of lamp filaments will be apparent from the following study.

Method. Connect your apparatus with the 110-volt circuit as shown in the diagram, using first a carbon filament test lamp. (The voltmeter is here connected around the ammeter so that the latter may read the true current through the lamp.) Put a fuse in the line to protect the ammeter. See Fig. 20.

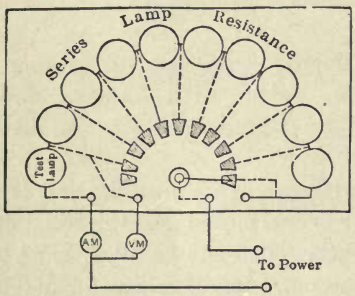
* From "The Loose Leaf Laboratory Manual," Timbie's Electrical Measurements, published by John Wiley & Sons, Inc.

Data and Results. Take readings of both the ammeter and voltmeter with all the lamps in the lamp board in series with the test lamp. Then cut out one lamp at a time, and take readings of the voltmeter and the ammeter for each step, until the last reading is for the test lamp alone. *The ammeter and the voltmeter should be read simultaneously.*

Compute the resistance of the test lamp for each current.

You have no actual measurement of temperature here, but as the current increases the temperature of course rises—very perceptibly for the last two or three readings.

Plot a curve from your data, using the resistances of the lamp as ordinates, the current as abscissae.



EFFECT OF TEMPERATURE ON THE RESISTANCE OF AN INCANDESCENT LAMP

FIG. 20.

What conclusion may be drawn regarding the effect of increase of temperature on the resistance of the filament?

Test in the same way lamps having a treated carbon filament and lamps having a metal filament as in the tantalum and tungsten lamps. Plot curves for each and compare the filaments as to their change in resistance with rise in temperature.

Addenda. Connect the voltmeter across the test lamp only, and note the ammeter reading. Compare this with the ammeter reading taken with the voltmeter connected across both the lamp and ammeter. Which ammeter reading gives the true current through the lamp, and why? Which voltmeter reading gives the true voltage across the lamp, and why? When would it be best to connect the voltmeter across both the ammeter and test piece? When across the test piece only?

Give detailed reasons for your answer. (See Timbie's "Elements of Electricity," p. 413.)*

PROBLEMS: 1. Measure on a Wheatstone bridge the resistance of the tungsten filament lamp at room temperature (20° C). Using the tempera-

* Published by John Wiley & Sons, Inc., New York.

ture coefficient of tungsten as .0051, and the resistance found for the lamp in the above experiment when on its rated voltage, compute the temperature of the filament when used on its rated voltage.

2. In an experiment like the above the voltmeter was connected across the test lamp only. If the resistance of the voltmeter is 16,500 ohms, the voltmeter reading is 110 volts, and the ammeter reading is .285 amp., what is the true current through the lamp filament?

THE WESTON DIRECT-CURRENT AMMETER

For pedagogic purposes the Weston ammeter with detachable shunts has marked advantages over the instrument with a self-contained shunt. The instructor may call attention to the fact that a " shunt " is really a part of the main conductor carrying the current and that only a small fraction of the total current passes through the movable system of the instrument.

A clear conception of the operation of a Weston ammeter may be obtained by means of a water-main analogy. The water main or trunk *A* through which water is flowing under pressure as in city water mains (Fig. 21), may be fitly compared with the conductor or bus-bar *F* (Fig. 22). The section *B* of reduced diameter corresponds with the shunt *E*, and the small pipes *C* may be compared with the leads *G*. It is obvious that, since the pipes *C* are of smaller dimensions than *B*, less water will flow through them; and, provided that the proportion between *B* and *C* is fixed and constant, the quantity of water flowing through the meter *D* will depend upon the total quantity flowing through *B*, and hence *D* may be calibrated to indicate the total flow of water instead of merely indicating the quantity passing through *C*.

On the same principle the scale of the instrument *H* may be figured to indicate any required amperage; but, although the total current flowing through *F* may be 20,000 amperes or more, the sensitivity of the movement of *H* to current is so great that only about 3/100 ampere is required to produce a full-scale deflection, and under proper conditions no current in excess of this amount will ever pass through *H*. The conductors *G*, together with the movable coil and resistors inside of *H*, are so proportioned that the flow of current through *H* is limited to the proper amount. But, nevertheless, instead of merely indicating the amount of current passing through its movement, *H* may

be calibrated to correctly indicate the total current flowing through *FEF*.

Finally, the quantity of current which will flow through *G*

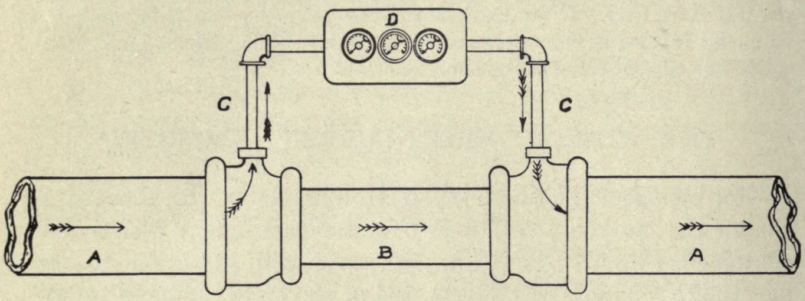


FIG. 21.

will depend upon the resistance of the shunt *E*; therefore, since shunts of different resistances and current capacities may be used in place of *E*, the instrument *H* may be used for an unlimited number of ampere ranges.*

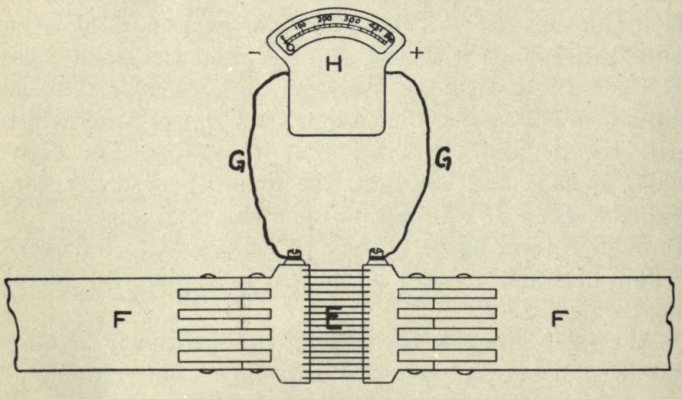


FIG. 22.

Instrument is a Model 11 Weston Illuminated Dial Ammeter.

* A shunt in electrical parlance was formerly defined as a resistor connected in multiple with an indicating instrument carrying the main current to reduce the current flowing through the latter; but, since the introduction of Weston instruments, " shunt " has become the trade name for a constant resistor of special form, having dimensions which will permit its practical use in series with a conductor carrying a current, independent of the current capacity of its indicating instrument.

EXPERIMENT XIII

THE STUDY OF AN AMMETER *

Apparatus: Ammeters of several types.

Ammeters may be divided into two classes: (1) Thermal—in which the movement of the index is secured through the change in length of a wire when heated by the current passed through it. The heat generated, and therefore the change in length, is here proportional to the square of the current; and

(2) Electromagnetic—in which the motion is due to the magnetic field produced when current is sent through the coils or coil of the instrument. Electromagnetic ammeters may be of three types; (*a*) Solenoidal; (*b*) permanent magnet; (*c*) electrodynamometer.

Data and Results. Examine instruments of several of the above types and report upon the following features for each:

1. The type of instrument.
2. The scale: range and graduation. Divisions—uniform or varying width. Why?
3. The construction:
   (*a*) Fixed parts; nature, material, construction and arrangement.
   (*b*) Moving parts; construction, bearings; control by which they are returned to zero; damping.
   (*c*) Shunt.
4. The connections by which the current enters and leaves the instrument. The circuit from binding post to binding post.
5. The resistance of each coil and of each shunt separately. The resistance of the instrument from terminal to terminal.

Explain the construction and arrangement of each essential part by simple diagrams, and show by a simple diagram how the parts are assembled in the complete instrument. Show the

* From "The Loose Leaf Laboratory Manual," Timbie's Electrical Measurements. John Wiley & Sons, Inc.

direction of current through each instrument and explain the reason for the deflection of the moving parts by the current. State in each case whether the instrument is suited for the measurement of direct or alternating current and why.

If the instrument is suited for both direct and alternating current, will the same calibration do for both kinds of power? Explain the reason for your answer.

By means of a millivoltmeter measure the millivolt drop across each instrument on full scale reading and compare this with the computed value. Account for any difference.

Show by diagrams the proper connections of the instrument to a line to measure the current taken by a motor.

PROBLEMS. The full-scale reading of a millivoltmeter is 100 millivolts. The resistance of the moving coil is 5 ohms.

(*a*) What resistance must a shunt be in order to be used with this millivoltmeter to have the scale read amperes?

(*b*) What must the resistance of a shunt be in order that the full-scale reading may indicate 10 amperes?

SUGGESTIONS FOR FURTHER STUDY

If the " drop " of a Weston station shunt of specified ampere capacity is 50 millivolts, what will its resistance be between its potential terminals?

Detach the shunt of a Weston ammeter with removable shunts, and measure the resistance of the instrument by means of a bridge.

NOTE: Minimum current should be used, and the battery key kept depressed to prevent the disturbing effect of currents induced by the motion of the movable coil.

If the drop of a shunt is 50 millivolts, the instrument for which it is intended must necessarily give a full-scale deflection with 50 millivolts. What then will be the amount of current required to give a full-scale deflection when the instrument is used without a shunt?

Explain what the effect would be if the leads from the shunt to the instrument were altered in length or resistance.

Determine the power (in watts) consumed by the instrument with shunt when in circuit with full-scale deflection.

THE WESTON DIRECT-CURRENT VOLTMETER

The Weston direct-current movable coil voltmeter consists essentially of a light rectangular coil of copper wire usually wound upon an aluminum frame, pivoted in jeweled bearings and mounted to rotate in an annular space between the soft iron core and the specially formed pole pieces of a permanent magnet. A light tubular pointer is rigidly attached to the coil and moves over a calibrated scale.

The current is led into and from the coil by means of two spiral springs, which serve also to control its movement. This movement is due to the dynamic action between the current flowing through the coil and the magnetic field of the permanent magnet. (See Fig. 23.) The pointer becomes stationary and the coil attains a position of equilibrium when the opposing forces of the springs equal the force caused by the rotary tendency of the coil. Since the magnetic field is uniform and the torsion of the springs proportional to the deflection, the scale divisions are practically uniform.

The well-known aperiodic or " dead-beat " quality of Weston instruments is produced in this type by Foucault currents generated in the aluminum frame when rotating through the magnetic field. These Foucault currents have a sufficient influence on the movement of the frame to cause it to come to rest almost instantly and without friction.

Ball, Hauptman and Bateman, when dealing with the subject of Potential Differences,* make the following statement, which we quote not only because it is well expressed, but also since it serves excellently to describe the proper conditions under which Weston voltmeters may be used:

" It has already been stated and shown in the previous experiments that, when certain electrical generators are employed, the P.D.'s between bodies charged from such generators may remain unchanged even when these bodies are connected by a conductor. This effect may, under proper conditions, be made the basis of measurement of P.D. The instruments generally employed for the commercial measurement of P.D. are based upon this principle. It must be noted, however, that the use

* Experiment No. 107, Laboratory Experiments, 1913.

of such instruments is admissible only when the current which passes through them does not alter the P.D. between the points to which they are connected."

If, therefore, an instrument is used to measure this P.D., it should, to perform its functions properly, be so constructed that it is extremely sensitive to current.

Weston voltmeters fulfill these conditions. It is true that they are conductors and require a small current to render them operative, and that there are conditions under which they would not indicate correctly. For instance, they could not be used with marked success to determine the static charge of a Holtz machine or a Leyden jar. Neither would they correctly indicate the potential of a Zamboni dry pile,* nor should they be used to directly test the e.m.f. of a Weston standard cell.

But since Weston voltmeters require only about 1/100 ampere with full-scale deflection, there will be no appreciable fall in potential when they are connected across any commercial source of current, ranging from a light and power plant to a dry cell.

An exercise similar to the following one, on the "Study of a Voltmeter," should in our opinion form part of every laboratory course in physics.

EXPERIMENT XIV

THE STUDY OF A VOLTMETER †

Apparatus Required: Voltmeters of several types.

Voltmeters may be of the types suggested in preceding experiment, or may be electrostatic.

Examine instruments of several types and report upon the following for each:

1. The type of instrument.
2. The scale: range and graduation. Divisions—uniform or varying width. Why?

* Deschanel's Natural Philosophy, 1870.

† From "The Wiley Technical Series," Timbie's Electrical Measurements. John Wiley & Sons, Inc.

3. The construction:
   (*a*) Fixed parts: nature, material, construction and arrangement.
   (*b*) Moving parts: construction; bearings; control by which returned to zero; damping.
   (*c*) Series coils. Double-scale instruments.
4. The connections by which current enters and leaves the instrument. The circuit from binding post to binding post.
5. The resistance of the instrument. Resistance per volt.

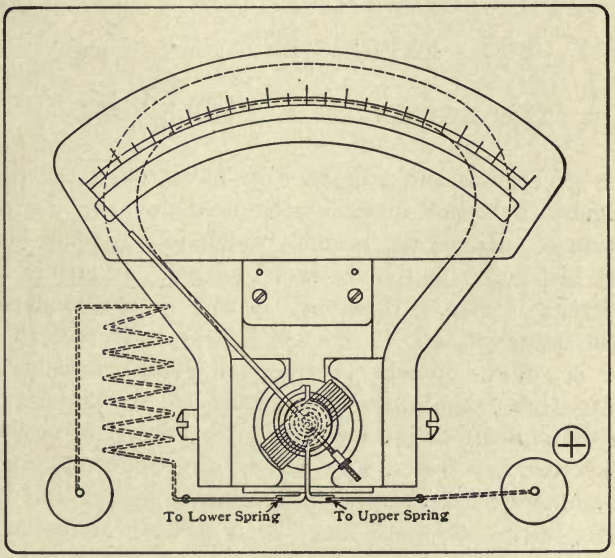


FIG. 23.

A Typical Weston Direct-current Movable-coil System.

Explain the construction and arrangement of each essential part by a separate diagram, and show by a simple diagram how the parts are assembled in the complete instrument. Show the direction of current through the instrument in each and give the reason for the deflection of the movable parts. Why does the reading indicate the difference of potential at the terminals?

State in each case whether the instrument is suited to the measurement of direct or alternating voltages and why.*

Suggestions for Further Study. Note or measure the resistance of one or more ranges of a Weston voltmeter of the movable-coil type.

Determine the current actually flowing through the instrument with full-scale deflection.

Determine the power (in watts) required to produce a full-scale deflection with different ranges.

Explain why a voltmeter the resistance of which is high (in ohms per volt) is preferable to one of low resistance.

EXPERIMENT XV

THE ACTION OF A SIMPLE CELL

Since generators and storage cells have taken the place of the primary batteries once largely used for the commercial production of current, the exercise which follows may be rated by many instructors as too abstract to deserve a place in a practical physics course. However, nearly every modern text book still retains it, and it remains for the instructor to decide whether it suffices merely to refer to Volta's discoveries, or emphasize their significance by means of an exercise which enables the student to produce current by chemical action.

Apparatus Required: Low-range, direct-current, 5-ampere Weston ammeter; low-range, direct-current, 1.5- or 3-volt Weston voltmeter; strips of sheet zinc, 2×6 inches; strips of sheet copper, 2×6 inches; glass jar, about 5 inches in diameter and 4 inches deep; 10 per cent sulphuric acid solution; mercury; copper wire.

Copper leads are to be soldered to the plates, the latter being

*For data relating to Weston movable systems, see also "Elements of Electricity," Timbie, Chap. XIV., "Physics," Mann and Twiss, page 169; "Practical Physics," Black and Davis, page 284; "Laboratory Manual," Black and Davis, page 64; "High School Physics," Carhart and Chute, page 371; "A High School Course in Physics," Gorton, page 405; "Electrical Instruments and Testing," Schneider and Hargrave, Chap. IV, "Lessons in Practical Electricity," Swoope, Lesson 18, and Weston Monograph B–4.

bent so that they may hang in the solution from the edge of the jar.

The voltmeter is first connected and deflection noted, which will be about 1 volt. See Fig. 24.

The ammeter is then substituted and deflection also noted. Current when circuit is first completed will be about 1 ampere; but since polarization rapidly sets in, the current at once decreases. Why?

Note the large number of hydrogen bubbles passing to the surface of the liquid from the zinc plate. Why?

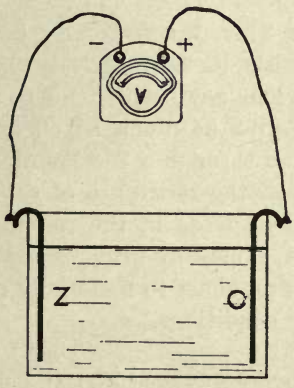


Fig. 24.

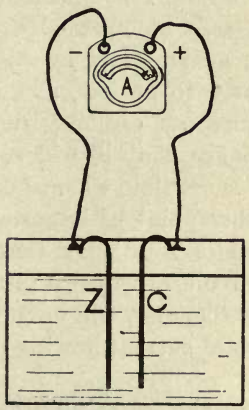


Fig. 25.

Weston Model 280 Voltmeter and Ammeter.

Substitute an amalgamated zinc plate. Note that very little hydrogen forms except when the circuit is closed, and that the current is comparatively constant. Why?

With the ammeter in circuit, decrease the distance between the zinc and copper poles, and note the increase in current. Why? See Fig. 25.

Disconnect the ammeter and try the above experiment with the voltmeter. Note that there is no appreciable difference in the e.m.f. Why?

With the plates hanging from the edge, connect both instruments successively, and note their deflections. Determine the

resistance of the circuit (cell, ammeter and leads) by the formula

$$R = \frac{E}{I}.$$

R = resistance of circuit; E = e.m.f.; I = current.

When both instruments are connected at the same time, the indicated e.m.f. of the voltmeter is much less than it is when the ammeter is not in parallel. Why?

NOTE. In making the above experiments the student may be permitted to connect the ammeter as stated, because the resistance of the cell is sufficiently high to limit the flow of current to a safe amount. He should, however, be cautioned about using an ammeter in this manner when the resistance of a cell is likely to be low, and consequently its current is large. For instance, an ordinary dry cell, when new, will have so low a resistance that it will sometimes give as much as 30 amperes for a short time when short-circuited through a Weston ammeter. Another point of importance is that the resistance of a Weston voltmeter is so high that a small decrease in the resistance of the circuit, of which it forms a part, caused by bringing the plates closer together, will have too slight an effect to materially change the total current flowing under the conditions.*

* See also Gorton's "High School Physics," Chapter XVIII; Fuller and Brownlee's "Laboratory Exercises," Experiment 68; "Physics," Mann and Twiss, page 58; "Physics Laboratory Manual," by Cavanagh, Westcott and Twining, and "Elements of Physics," by Hoadley.

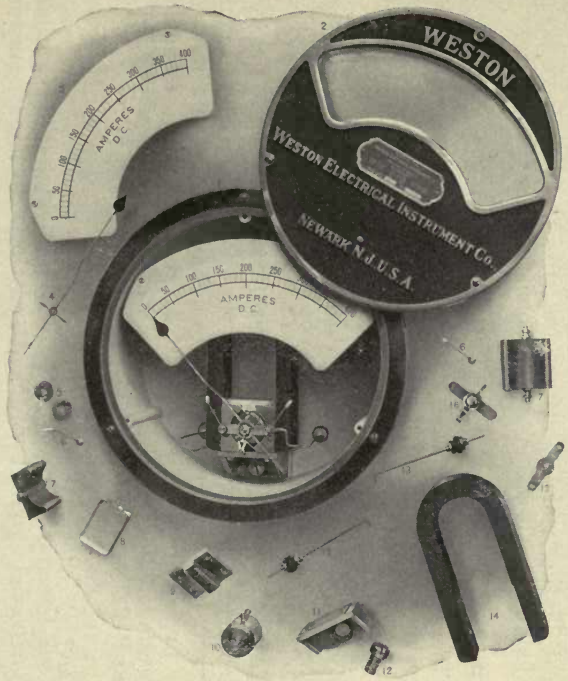


FIG. 26.—Interior View and Parts of a Standard Commercial Switchboard Ammeter

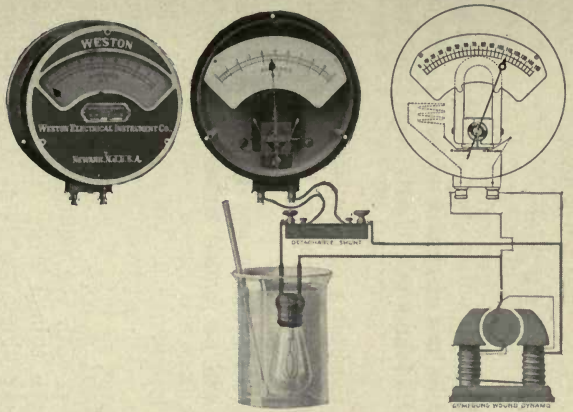


FIG. 27.—Experiment for Teaching that the Electrical Energy Required to Operate a Lamp is Converted into Heat.

The illustration shows, from left to right, a standard commercial ammeter, a standard commercial ammeter with front removed, and the internal electrical circuit of a switchboard voltmeter.

It also depicts the proper method of connecting the ammeter and voltmeter in circuit, and denotes the proper connections for the experiment.

In order to perform the experiment accurately and instructively, reliable electrical measuring instruments are essential.

Switchboard types are shown for the sake of simplicity of interior views, but portable instruments are more convenient to use if available.

The experiment can be performed with alternating-current apparatus and instruments if necessary.

Data relating to this experiment are contained in Weston Monograph B-2.

CO-OPERATORS

We publish herewith extracts from a few of the many unsolicited, but very welcome letters of commendation received since we issued Monograph B–4 and our charts, early in the spring of 1914.

We illustrate on page 71 facsimiles of the latter, but their extremely reduced dimensions cannot do justice to these artistic and useful productions.

The actual dimensions of these charts are $15\frac{3}{4} \times 17\frac{3}{4}$ inches.

As already stated, copies will be mailed to science teachers upon request, free of charge.

Bates, Lew. W., Hiram, Ohio:

"Some time ago, I received a copy of your Monograph B–4. I am very much pleased with the publication and think that I shall be able to use some things in it. I wish to thank you for the work you are doing along this line. I am anxious to know if you still have copies of the previous numbers of these publications and if so, how they may be obtained."

Beaman, Charles O., State Normal School, Brockport, N. Y.:

"Please accept my thanks for the copy of Experimental Electrical Testing which you sent me. As far as I have been able to look it over it seems to have some very fine experiments."

Black, Prof. N. Henry, Roxbury Latin School, Boston, Mass.:

"Allow me to acknowledge the receipt of Monograph B–4 on Experimental Electrical Testing.

"I have found the experiments very suggestive and I am sure other teachers will also find them helpful.

"Would you be good enough to send me two copies of Monograph B–3, which I can't seem to find anywhere."

Blair, Nathan D., Mechanics Institute, Rochester, N. Y.:

"Recently I received through the mail a copy of your Monograph B–4. After carefully examining it I would like to see the preceding ones if they are as good as B–4. I should be very glad if you will be able to send me Monographs B–1, B–2 and B–3."

Bowne, A. G., Cedar Rapids, Iowa:

"Your letter of the 8th at hand. Replying, will say that I have received your instrument catalogs, but have never

received Monographs B–1, B–2 or B–3. I have heard much about these monographs and would like to have copies of these very much if you still have them.

"Just the other day I received your Monograph B–4. I have looked it over and am very much pleased with the work set forth in it. I feel that this kind of work is worth putting before the pupils. We are planning to do more of this kind as soon as we can get equipment."

Boynton, W. P., Prof. of Physics, University of Oregon, Eugene, Ore.:

"Your two charts illustrating your switchboard instruments were delivered to the department of Physics a week or two ago, and were promptly hung up in our general laboratory. We have found them useful there, and have also taken them into the classroom to aid in explaining the construction and operation of commercial instruments.

"They are of such evident value that it is hardly necessary for me to say that we appreciate them very much indeed, and if we find them useful, with a very excellent equipment of real instruments, they ought to be even more of a boon to schools whose resources and equipment are more limited.

"While I am writing I want to express my appreciation of your miniature instruments, of which we have recently purchased a small assortment. They are the real thing, as accurate as they look, and all that is needed for practically all of our work involving commercial instruments. Personally I believe all High Schools should to a great extent select a type of experiment in Electricity which can be performed with the commercial type of instruments, and replace their galvanometers as far as possible with such instruments as these."

Bridgman, Prof. P. W., Jefferson Physical Laboratory, Harvard University, Cambridge, Mass.:

"Mr. F. H. Beals, whom I recently met in Washington, has suggested that I write to you asking for your Monographs dealing with electrical instruments for courses of instruction in colleges or secondary schools. This is a matter in which I am interested, and I would greatly prize the possession of these documents."

Burrows, J. Austin, West High School, Des Moines, Iowa.:

"We wish to acknowledge the receipt of the charts which you sent us, and thank you for the same. We highly endorse your policy in sending out these to the schools, and acknowledge their helpfulness in the development of electrical subjects in our physics class. May we go on record as wishing to encourage

such co-operation? We believe these charts and such other helps will be of real service to us.

"I am interested to know what your arrangement is regarding your Monographs. Do you send them out gratis,* or do we order them from you and pay you in return? I wish to obtain some of these from you and would appreciate your instructions as to how this may be possible.

"I wish to acknowledge the receipt of the Monographs which you sent me the latter part of last week, and please accept my thanks.

"I expect to use some of the experiments which are found therein, in my work next year, and I am sure they will be helpful to me throughout the year. I shall appreciate the receipt of any further monographs which you will get out in the near future, as there is no doubt in my mind that they are practical experiments, and many of them should be included in a practical course in physics. It may be of interest to you to know that we expect to use your instruments in our laboratory next year, as I have included six of them in my requisition for supplies for the coming year."

Cory, Merton M., Michigan Agricultural College, Dept. of Physics, East Lansing, Mich.:

"Some time ago I received one of your electrical charts. Owing to a press of college business I have neglected to acknowledge receipt of same. We appreciated the charts very much and intend to have them framed and hung in the laboratory.

"Your latest Monograph B–4, just received and it is very good. One thing disappointed me, viz., the absence of any experiments for resistance measurements by the drop of potential method.† I realize that this method is so familiar to Instructors that it is assumed the student becomes perfectly familiar with the test by measuring the resistance of one or two coils of wire.

"It is my experience with our Junior Engineers that they have only a hazy idea of how the work should be done. Therefore it seems to me that high school students should be thoroughly drilled in the use of the voltmeter and ammeter for resistance measurements.

"Trusting that you will not consider the foregoing a criticism on your very instructive monograph, but more of a lament from one who pins his faith in Ohm's Law."

* Compiler's note. Yes, in reasonable quantities we send all of our publications to instructors free of charge.

† Compiler's note. These experiments will be found in Monograph B2, a copy of which had not been received by Prof. Cory at the time of his writing.

Dry, Richard R., Technical High School, Buffalo, N. Y.:

"I have received your Monograph B–4, and am very well pleased with it. If I can in any way be of assistance in future publications of a similar character I shall consider it a privilege."

Fee, Lewis H., Science Dept. Everett High School, Everett, Wash.:

"I am in receipt of an advance copy of your Monograph B–4, EXPERIMENTAL ELECTRICAL TESTING. I should like 4 additional copies sent to my address here.

"I believe these Monographs will supply a long felt need among the science teachers and I hope you will continue to publish the same. I have already placed the copy of B–4 in the hands of one of my laboratory sections and they are working out one of the experiments given there as a regular laboratory exercise. I shall use more of them for the same purpose."

Flanders, Milton M., Bliss Electrical School, Takoma Park Washington, D. C.:

"I beg to acknowledge with thanks the receipt of a copy of your recently published Monograph B–4. It is interesting and practical. While the nature of our course is for the most part in advance of the work covered, it seems admirably suited to the purpose for which it is intended.

"Since our students come largely from high schools where the electrical training is so often superficial and too theoretical, it should indirectly be of help to us.

"We would appreciate a few extra copies when you have them for distribution."

Gilmore, L. P., Head Dept. Science Oregon State Normal, Monmouth, Ore.

"I have at hand your Monograph B–4 and wish to say it is just the kind of work I have been looking for. You can't do too much of it. Will you send me copies of your Monographs 1, 2 and 3, as I do not have them.

"Another matter, this school is equipped with apparatus of the ninteenth century type and we are trying to replace it with up-to-date materials. I shall treat it as a favor if you will give me a list of apparatus which you think would be the type to get for a live and up-to-date course in physics. I mean chiefly such apparatus as you make. If possible have that list here by June 1st, so that we may be able to place an order early. I shall value such a favor and think I can in return promise an order. In any event I shall make a substantial effort toward that end.

"Thanking you very kindly for your most helpful monographs and information, I am."

Glenn, Earl R., Sec'y Froebel School, Gary, Ind.:

"I have carefully examined the advance copy of your most recent monograph. It is a most suggestive and helpful book for physics instructors. It is hardly necessary to add that when the equipment is purchased for the electrical courses of this school, your company will receive all orders for electrical measuring instruments."

Greenlaw, Frank M., Head of Science Dept., Rogers High School, Newport, R. I.:

"It gives me pleasure to acknowledge the receipt of set of Monographs B–1, B–2, B–3 and B–4, together with two wall charts. I am sure that these will be of much value in instruction, and expect to order in the near future a number of Weston Instruments."

Grotts, W. F., Raymond Public Schools, Raymond, Ill.:

I wish to thank you for a copy of Monograph B–4, which I have examined with interest. I think your idea is going to be of great assistance to teachers. We are always working for practical suggestions in this subject and eagerly seek helps like your Monographs.

"I would be very well pleased to receive copies of Monographs preceding B–4. If it happens that you do not have avialable copies of these please keep my name on your mailing list.".

Harkey, Theodore S., Hyde Park High School, Chicago, Ill.:

"Some time in the winter we received three or four beautiful charts of your meters of the sizes suitable for framing. At various other times we have received monographs, the last one labeled "Monograph B–4" and dated April, 1914. For these and other courtesies I want to express my heartfelt thanks.

"It seems to me that the work you are doing in the publication of these little pamphlets is the most important influence now felt throughout the schools of the United States in bringing to the attention of the teachers of science standard apparatus and the most valuable experiments that can be carried out with them. Till recently your meters were so high-priced that it was impossible for schools to think of purchasing; but the models you now have for sale are low-priced enough and accurate enough for all ordinary users. I believe you have the gratitude of the entire teaching body in the excellent work you have done in these two lines.

"In outfitting our new laboratory here, we purchased sixty-our of your new meters, Model 280."

Hazelrigg, T. Roy., Missoula County High School, Dept. of Physics, Missoula, Mont.:

"First let me thank you for Monograph No. 2, Joint Committee Series and also for B–4, Experimental Electrical Testing by students. I find that these are full of the very best of suggestions, and let me say right here that it is my intention to install a complete line of your instruments in our laboratories as soon as I can get the appropriation.

"We have been buying our supplies of the Central Scientific Company of Chicago. Will it be as cheap for us to buy our Weston instruments through them as to send direct to you?* It saves opening up two accounts.

"Have you any ideas to offer concerning the wiring of a model laboratory for the installation of your instruments? I thought that perhaps you could give me some valuable suggestions, as you perhaps have offered suggestions and sent diagrams to other schools. I think that you have entered into a great field both from an educational standpoint and also from an advertising as well. Though perhaps the latter is the ultimate aim, I am sure that we educators are glad that you have instituted the plan.

"I am starting in to plan a model laboratory for our school, though it may not come to materialize for some time. Also I have been thinking of a second-year course in Electricity, or at least with the emphasis on that branch of Physics. Can you offer any suggestions along that line or refer me to anyone? Perhaps you can offer some helpful bibliography too. You make reference to many books in your publications without definite directions as to the publishers.†

"If this letter will guide you any in your endeavors I am glad and shall be glad to co-operate with you in your campaign for '*real physics.*'"

Irish, F. M., Instructor in Physics, Tempe Normal School of Arizona, Tempe, Arizona:

"Our laboratory has received from your office two very beautifully executed charts illustrating the construction and use of standard electrical measuring instruments.

"We are certainly glad to have these charts and will find them of the greatest use in explaining the use and care of such instruments to our classes in physics, especially in view of the fact that we have purchased several of your miniature voltmeters and ammeters, and expect to add more of them to our equipment as soon as finances permit.

* Compiler's Note. Yes.

† All of the text-books to which we refer may be purchased through D. Van Nostrand & Co., N. Y., and Chicago, and other book dealers.

"The charts occupy a prominent place on the laboratory wall and attract much attention and interest.

"Please accept our thanks for these handsome aids and also for the various educational pamphlets we have received from your hands at various times, and of which we have made good use. You are rendering great assistance to instructors in these lines."

Jester, Simeon Van T., Friends' High School, Moorestown, N. J.:

"I was fortunate enough to receive your Monograph B–4 and it is the greatest help that has ever come my way. Please send me a copy of each of the monographs that have been issued.

"Please advise me about the purchase of voltmeter and ammeter and send any literature that you may have at hand."

Johnston Earl Lynd, Fort Lupton Consolidated Schools, Fort Lupton, Colo.:

"We thank you for the pair of charts, which arrived safely. We are sure that in our science department next year they will be viewed with pleasure and profit by all those students interested in the subject of electricity. We hope you may get out similar charts in the future. We also appreciate the work and care manifested in the material found in your monographs, and again we hope you will add to this series in the future."

Lowwater, Prof. F., Rockford College, Rockford, Ill.:

"Thank you for your Monograph B–4. I have not received B–1, B–2 nor B–3, but shall be pleased to do so.

"I quite appreciate your desire to work in conjunction with science teachers that the teaching of science in schools may be truly interesting to the students.

"This part of the country seems to me to be more utilitarian than the East. With most of my students (College girls) it is the essentially practical that interests them, almost solely the practical domestic. For instance, the melting-point of butter arouses real interest, whereas the melting-point of paraffin falls quite dead. I am therefore on the lookout for the experiments that will both arouse their interest and give them scientific training at the same time. In college work, of course, the latter is essential."

McClellan, John H., The Emerson School, Dept. of Physics, Gary, Ind.:

"I was certainly glad to receive your Monograph B–4. I have been using the experiments suggested with great profit to my class in Electricity. I find that laboratory work of the character outlined in your monograph adds greatly to the

interest taken in the work by the students. I should like to be placed on your mailing list for any future monographs. I hope later to be able to send you a problem or so that we have worked out.

"The great difficulty in many of the schools of this State is the lack of anything like reliable instruments for the work you outline. I believe a set of your instruments would be more valuable to a Physics Dept. than all the antiquated electrical apparatus which most laboratories possess.

"Will you please forward to my address a catalog of your miniature instruments, and oblige."

Metzger, R. D., Salem High School, Dept. Science, Salem, Ohio.:

"Monograph B–4 at hand. This is my first year here and am sorry to say that none of your previous Monographs have come to my notice. My examination of this one, B–4, shows me that I have missed some valuable aids. I certainly believe in teaching the use of instruments. We are starting to build a modern H. S. building and I hope that I may be able to influence equipping the Physics laboratory with the useful and practical modern apparatus that is absolutely needed."

Moran, Clement, Starkey Seminary, Lakemont, N. Y.:

"Your Monograph B–4 has been received. We feel that this is the best one of the series and we are sure it will be of much value to teachers and students of science.

"We are keeping them on file in our laboratory, but with the end of this year I am leaving my present position and feel that I would like to have copies that I might consider my own personally to take with me. If you can supply me with a copy of B–4 or the whole set I would appreciate the favor."

Munson, W. H., Winona, Minn.:

"The monographs came to hand to-day. Thank you for your courtesy.

"I cannot be sure how soon I shall be in the market for instruments, but I shall surely correspond with you whenever that time comes.

"I wish to express individually my appreciation of your efforts to correspond with and to co-operate with the teachers of the country in the furtherance of good work in the classroom."

Olwell, A. M., Marshall High School, Chicago, Ill.:

"Some time since I received a copy of your B–4 Monograph. I am very thankful to you for this manual.

"I have used it with good results in my laboratory work in a first year electricity class.

"Such helps as this book will do much toward dragging the

old tangent galvanometer—plunge battery physics teacher out of the rut. I wish you the greatest success in your campaign for modern practical physics instruction."

Osborn George A., Librarian, Rutgers College Library, New Brunswick, N. J.:

"We have received from the College office the copy of 'Experimental Electrical Testing by Students,' which you sent to them.

"May I ask that we be placed on your mailing list for future publications, and that they be addressed to Rutgers College Library?

"The subject is one for which we have constant calls for material, and we shall much appreciate receiving your publications."

Rayman, E. E., Lincoln High School, Cleveland, Ohio.

"I want to most cordially thank you for the Monograph B–4 which reached me this week. The strong feature of B–4 is that it is practical life, what is 'doing' to-day. I have no patience with obsolete subjects. I want what is serviceable to-day and in the future. Consequently, it gives me pleasure to be brought into communication with people who are improving present practices. Again thanking you and congratulating you on your enterprise, I am."

Rupp, R. G., Hammond High School, Hammond, Ind.:

"I note that you have just issued Monograph B–4, on Experimental Electricity Testing; I recall with pleasure the monographs which you have issued from time to time and I hope that I may receive the new one; I think you have the right idea.

"We have in our laboratory here, two each of your Model No. 280 voltmeters and ammeters; they are giving satisfaction to the very highest degree; they are so far ahead of the ordinary high school galvanometer that I would not think of returning to the latter instrument for high school use. I hope that we can add to our equipment the coming year and that the list will include some electrical apparatus."

Shannon, James D., Prof. of Physics, St. Louis University, St. Louis, Mo.:

"Allow me to thank you for the two science charts which you lately sent to us and which were referred to me. We have had them framed and they are now hung up in our physical laboratory.

"These charts have already been of real service and will

continue so to be. The one showing the interior and parts of an ammeter is especially valuable.

"Allow me to take an opportunity, which I had intended to seize before, to thank your Company for having prepared a line of instruments—ammeters, voltmeters and wattmeters—of standard grade and first-class workmanship yet of very moderate price, suitable for use in students' laboratories. Such instruments offer a solution of a very real problem that hitherto had confronted the professors and instructors in laboratories where it was desired to instruct a large number of students in modern methods of electrical measurements, and where at the same time the resources at hand are limited. Our use of these instruments has tended to strengthen the good impression produced by the first announcement of their preparation.

"Again thanking you for your charts and your Monographs for Science Teachers."

Smith, Ernest R., Vice Principal North High School, Syracuse, N. Y.:

"The latest Monograph (B–4) has arrived. I read every word at a sitting and was delighted. I believe you have made a very useful contribution to physical science teaching.

"I gladly add my testimony to the effect that Weston instruments have proven extremely satisfactory and have never given a moment's trouble. I have several different models (18 in all) in constant use, and shall order more as soon as our appropriation appears."

"Let me know if I can help the good work in any way."

Spice, Robert, Cooper Urion, Dept. Chemistry, New York:

"I beg to thank you for the four Monographs which came to hand this morning.

"I wish to say that these Monographs are not only interesting and of much practical value, but they are so artistically produced that they are a pleasure to look at."

Thomas, J. M., St. Mary's College, Van Buren, Maine.

"Having come across your Monograph B–4, I have found it so much to my liking, that I must have all the others, whatever may be the charge.

"Please send me also the catalog of your instruments for students."

Turner, George M., Dept. of Physics and Chemistry, Masten Park High School, Buffalo, N. Y.:

"The advance copy of Monograph B–4 entitled 'Experimental Electrical Testing' is just at hand. It is a very helpful publication and a credit to your company. I shall be glad to obtain two or three more copies when convenient."

Wittig, Prof. Gustav, University of Alabama, College of Engineering.

"Beginning in a few weeks, I shall have a large class in physics in our summer session; judging from previous years it will number from 125 to 150, chiefly teachers in schools throughout the State. I hasten to add that they are not teachers of physics, though.

"For use with this class I should like to have extra copies of your charts, and should very much appreciate your sending me another set.

"The sixteen instruments were received in excellent condition, though we ordered them a little too late to get as full service out of them as I had hoped for this year. I enclose a hastily-made rough sketch of a wooden mount I had made in our shop for each meter. (Regret I have not time to give you a better one). Any high school with a manual training department can do the same. The dimensions are merely suggestive. When placed on a laboratory table the inclination of 45° to the horizontal makes the meter easy to read, and the stable base prevents tumbling. If you can use the sketch you are welcome to it." *

Zehetner, A. W., Instructor in Physics, Dubuque High School, Dubuque, Iowa:

"I received the voltmeter and ammeter which you designed specially for my lecture table use and cannot say too much in praise of them. A year ago I found our physical laboratory flooded with toy apparatus and was entirely lost in teaching electricity until I obtained your instruments. At present I am obliged to use the inferior instruments and am calibrating them, using yours as standards. It is surprising how the unreliability and defects of these cheaper instruments are revealed in this way. I am making use of this difficulty by giving my students several calibrating jobs, which are instructive, in more than one way, to teacher as well as student.

"We have framed the two charts you recently sent us, and they make not only excellent wall pictures in keeping with the atmosphere of the laboratory, but are proving very instructive.

"Your Monograph B–4 is also greatly appreciated. I am very glad you have entered this field and would appreciate greatly any future favors or information you have to offer."

* Compiler's note. The wooden mount referred to is intended for supporting Model 267, Weston Switchboard Voltmeters and Ammeters. It is well designed. We will send a sketch on application.

PRACTICAL MEASURING APPARATUS

MONOGRAPH B-3

SECOND EDITION, AUGUST, 1914

"ACCURACY is the first requisite for success in all original research, and accuracy cannot be attained when crude make-shifts are employed in place of standard apparatus."

WESTON ELECTRICAL INSTRUMENT CO.
NEWARK, N. J.

THE NEW JERSEY STATE SCIENCE TEACHERS' ASSOCIATION

PHYSICS COMMITTEE

FREDERICK H. BEALS, Barringer High School, Newark
HOWARD McCLENAHAN, Princeton University
FRANK F. THOMPSON, Rutgers College
T. GILBERT McFADDEN, Jersey City High School
C. O. VOEGELIN, Central High School, Newark
MISS ADELE CAZIN, Montclair State Normal School
W. N. MUMPER, Trenton State Normal School

NEWARK, N. J., April 2, 1913.

Weston Electrical Instrument Co.,

Newark, New Jersey.

Dear Sirs:

As a member of the Joint Committee on Physics I am interested in having you acquaint teachers generally with the Weston Electrical instruments now well known throughout the commercial electrical world.

From my teaching experiences in California and the east and from my travels of some twelve thousand miles in one season visiting college laboratories in search of equipment, I am strongly of the opinion that you are doing a distinct service to the teachers and to the schools of the country by letting them know through your monographs that you make electrical instruments that are not only standard and suited to hard commercial service but are perfectly adapted to hard school use and are to be had for a price within the reach of the high schools.

Yours sincerely,

Frederick H. Beals.

Chairman of Physics Committee of the N. J. State Science Teachers' Association.

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PRACTICAL MEASURING APPARATUS

THIS Monograph contains a description of several models of Standard Weston Indicating Instruments that have been specially selected to meet the requirements of high school laboratory and lecture work. We desire to impress science teachers with the fact that the instruments herein specifically recommended are identical in principle and construction with the Weston instruments which the student will be required to use and understand later in practical work. The instruments referred to possess all of the characteristics of excellence relating to mechanical and electrical design and workmanship peculiar to all Weston products.

These instruments are guaranteed, and the service they will render with respect to accuracy, sensitivity and durability cannot be equaled by apparatus of other manufacture.

No attempt has been made in this monograph to offer a detailed description of the instruments illustrated, because such information is given in complete catalogs with price lists, which will be mailed upon request.

It will give the Technical Staff of this Company the greatest pleasure to be of any possible assistance to all instructors who intend to modify, extend or introduce a course in physics. If they will write to us giving all essential details, we will promptly send information in relation to the electrical apparatus that should be procured, and when feasible we will advise from whom it may be purchased to the best advantage.

Any suggestions we may make in relation to obtaining apparatus not of our manufacture will necessarily be unbiased and disinterested, since we are neither manufacturers of nor dealers in electrical supplies, and our business is strictly limited to the production of Weston standard and commercial electrical measurement apparatus.

Therefore it must be understood that our motive in recommending apparatus not of our manufacture is prompted only by a desire to assist instructors.

We purpose to improve the free services which we have always rendered to teachers. We extend a cordial invitation to all instructors to visit our factories and laboratories if possible.

Whenever feasible, we will, upon request, send a representative for the purpose of consulting with teachers, but where location prevents personal conferences, we will endeavor to give our best services by letter.

SWITCHBOARD AMMETERS AND VOLTMETERS FOR DIRECT CURRENT

1. These are typical switchboard instruments extensively used in light and power telegraph and telephone stations, laboratories, etc. See Figs. 1 and 2.

2. "Iron-clad" and designed to be unaffected by external magnetic fields.

3. Long and uniformly divided scale.

4. Dead beat movement, operated on the well-known Weston movable-coil and permanent-magnet principle.

MODEL 24 AMMETER

FIG. 1.

MODEL 24 VOLTMETER

FIG. 2.

5. The ammeters are regularly furnished with self-contained shunts up to 200 amperes, but may be equipped with detachable external shunts if so ordered. If a series of external shunts of different capacities are ordered, one ammeter may be made to take the place of several, thereby obtaining the advantage which a number of instruments afford at a low cost.

6. The voltmeters have self-contained resistors for all ranges up to 300 volts.

7. Voltmeters can be furnished with two ranges such as 150 and 3. List prices are from $15 to $26.50, according to ranges of instrument required.

Complete prices, recommendations and specifications sent on application.

8. Guaranteed accuracy, 1 per cent.

WESTON PORTABLE WATTMETERS

Model 310

1. These instruments may be used on either direct- or alternating-current circuits.

2. They are shielded from external magnetic fields; and their indications are not influenced by changes in temperature.

Fig. 3.

3. They are all made double range both in current and voltage, and in all capacities up to 75 K.W.

4. The current ranges can be changed by connecting the field-coil sections either in series or in multiple by means of links.

5. The field coils will stand an overload of 100 per cent

without undue heating and the potential coil may be overloaded 66 per cent.

6. The 2.5/5-ampere, 150/75-volt instrument is especially adapted for laboratory and experimental work. Its range is 750, 375 and 187.5 watts. The maximum current capacities are 5 and 10 amperes, and the maximum voltage 250 and 125.

7. The instrument is very useful for determining the power consumed by incandescent lamps and electrically heated devices such as flat-irons, toasters, water heaters, etc. It will also serve excellently for checking recording meters.

8. The subdivisions of the scales in these wattmeters are uniform throughout.

9. Guaranteed accuracy $\frac{1}{4}$ of 1 per cent. List price $70.

WESTON PORTABLE VOLTMETERS OR AMMETERS

MODEL 45

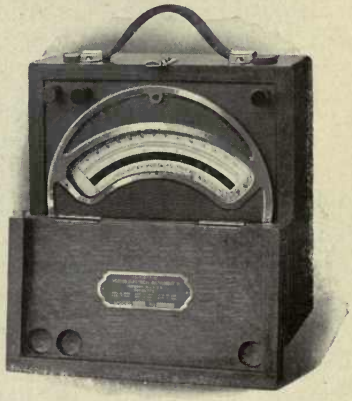

FIG. 4.

1. This is the same instrument which the student will be called upon to use in later practical work, and is therefore to be distinguished from makeshift indicators generally advocated by dealers. See Fig. 4.

2. It possesses all of the characteristics of excellence of mechanical and electrical workmanship and design common to all Weston products.

3. It is made and thoroughly guaranteed by the concern occupying the position of producing instruments that are commonly acknowledged to be the standards of the world, and is guaranteed to an accuracy of 1 per cent.

4. It is perfectly " dead beat," has a long scale and is direct reading.

5. It operates on the well-known permanent-magnet movable-coil principle.

6. The voltmeters may be made with one, two or three ranges, for example, for 150 volts; 150 and 3 volts or 300, 150 and 15 volts.

7. The ammeters may be made with one shunt self-contained or with a series of external shunts of different capacities, under which latter circumstance one instrument may be made to serve the purpose of several instruments of different ranges.

8. These instruments are "iron-clad" to shield them from the influence of external magnetic fields.

List prices are from $25 to $37 according to range of instrument required.

Complete catalog and price list sent on application.

CLASSROOM VOLTMETER AND AMMETER FOR DIRECT CURRENT

Model 323

This instrument has been specially designed for instructors' and students' use.

It combines in one mounting:

1. A voltmeter with with 3 ranges, 150, 15 and 3 volts.
2. An ammeter with as many ranges as may be desired.
3. A 0.050-volt millivolt meter.
4. A milliammeter (see description).

Model 323 has two separate and independent movements in one case, each provided with terminals and a 5-inch uniformly divided scale.

It is operated on the well-known Weston movable-coil, permanent-magnet principle.

It may be set at various angles by means of a thumbscrew, so that its scales will be perpendicular to the plane of vision. This feature makes it particularly suitable for classroom demonstration.

The finish is durable dull black japan, bringing out the scales in sharp contrast, so that they may be distinctly read at a considerable distance.

Zero adjusting devices are provided for each movement.

The voltmeter is regularly made in three ranges, 150, 15 and 3 volts, but other ranges will be supplied if preferred, at a slightly increased price.

The movable coils are very light, and their motion is practically dead beat, so that their pointers come to rest almost instantly after being deflected.

MODEL 323

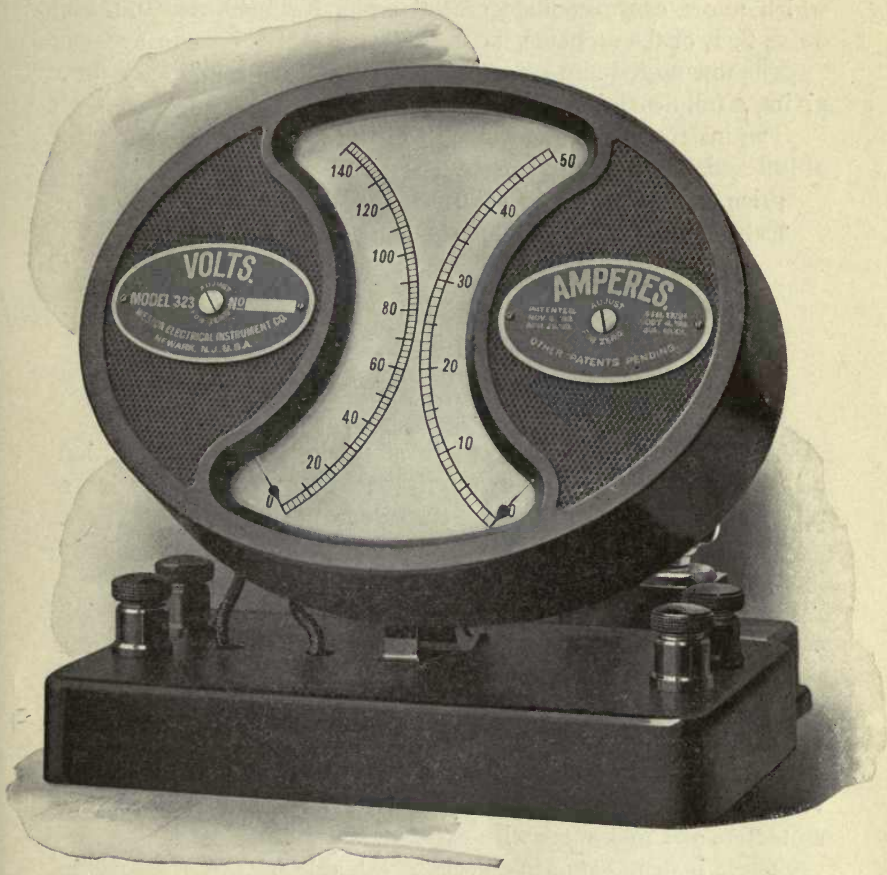

FIG. 5.

The ammeter movement is connected with the shunt in use by means of flexible leads and thumbscrews.

Shunts have a standard drop of 50 millivolts, and may be had in any range from 1 to 100 amperes, and can be easily attached or removed without tools.

The instrument is regularly supplied with two shunts, one having 10 amperes, and the other 1 ampere capacity.

Additional shunts of any desired range up to 100 amperes can be supplied; but since the ammeter has a scale with 100 divisions, we recommend that shunts be ordered of ranges which allow easy readings of the scale, for instance, 100, 50, 20, 5, 2, 1, or 0.5 amperes.

The unshunted ammeter may also be used as a milliammeter, giving a full deflection with 25 milliamperes.

The instrument is guaranteed to be correct within 1 per cent of full scale value for all ranges.

Price complete with two shunts $35 list.

Extra shunts 1 to 100 amperes, each $3.

WESTON VERTICAL-SCALE PORTABLE INSTRUMENTS

Model 264

The Model 264 is designed to stand in an upright position on a desk or shelf above a working table, and is made with a relatively heavy base in order that it may not easily be upset.

The scale is $4\frac{1}{8}$ inches in length and is vertical, and hence may be easily and clearly observed.

In general, the Model 264 instruments possess the same high order of merit as other Weston portable direct-current instruments.

Each instrument is equipped with a zero-correcting device, and connections are regularly made from the rear. The cases are handsomely finished in dull black enamel.

Model 264 instruments are made as galvanometers, millivoltmeters, voltmeters (range not to exceed 150 volts), milliammeters and ammeters with external shunts.

These instruments are especially valuable for students' use in laboratory work, and are particularly recommended for that service on account of their high accuracy, great durability, convenience and low cost.

A very useful instrument for the student is one calibrated 50–0–50 (zero-center 100-line scale), having a resistance of 2.5 ohms. The current required for full-scale deflection is .050 ampere, or .001 ampere per scale division. Such an instrument

may be easily converted into a voltmeter by adding an external multiplier having a resistance of 20 ohms per volt.

Model 264 milliammeters have been made as differential instruments for use in balancing two circuits, and are extensively in use in this form in connection with telegraph bridge circuits. Other uses for these instruments will suggest themselves to electrochemists and to customers in general who have long sought a compact, readily movable and easily read instrument of high grade with a vertical scale.

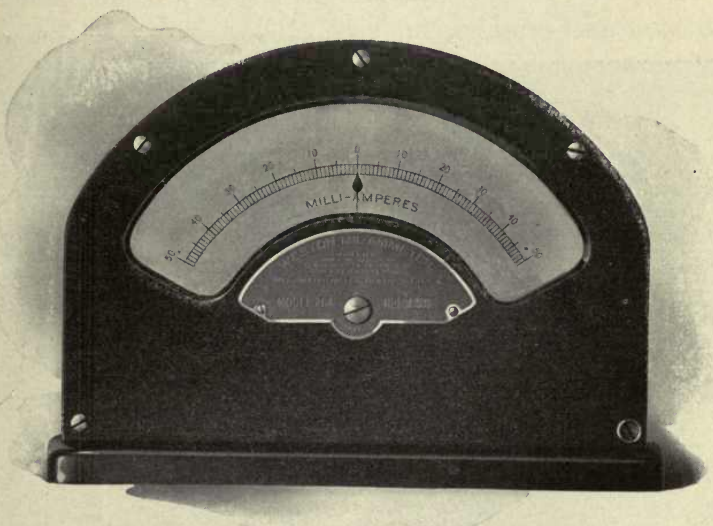

FIG. 6.—Vertical-scale Portable Instrument.

Price List:

Millivoltmeters ranging from 0–100 to 0–1000, zero in center or zero to left	$20.00
Voltmeters ranging from 0–1 to 0–150 volts, zero to left	20.00
Voltmeters (ranges as above) zero in center	21.50
Ammeters ranging from 0–1 to 0–150 amperes	23.00

(All ammeters having a range above 5 amperes are provided with external shunts having a drop of 50 millivolts. Ammeters up to and including 5 amperes are made with self-contained shunts.)

Milliammeters ranging from 0–50 to 0–750 milliamperes. $20.00

Ammeters and milliammeters may be had with zero in center, without extra charge.

An additional charge will be made for differential milliammeters.

A catalog giving lists of ranges regularly manufactured will be mailed on application.

WESTON STUDENT GALVANOMETER

MODEL 324

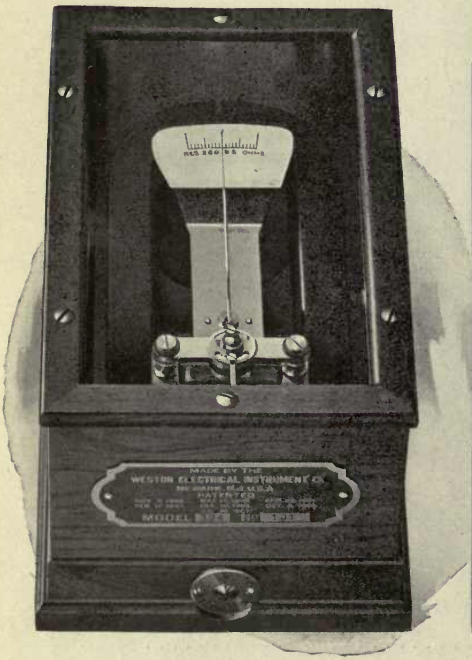

FIG. 7.

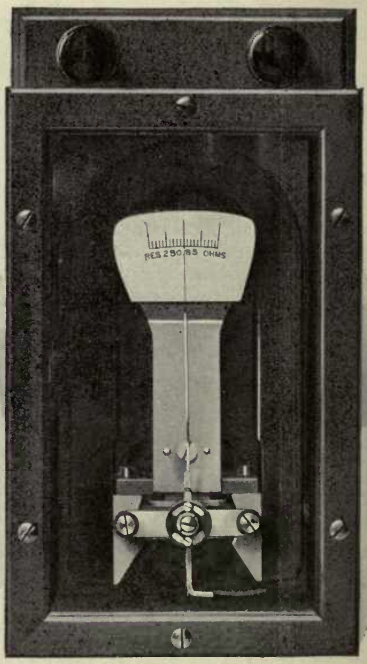

FIG. 8.

Designed and prepared with special reference to the requirements of students in high schools, training schools and collegiate preparatory schools.

This galvanometer meets a long-felt requirement for a thoroughly reliable yet extremely sensitive indicator of slight potential differences.

Advantages over Suspension Types

1. Has an extremely concentrated magnetic field and a sensitivity such that it gives a scale deflection of 1 mm. with 1 volt through 500,000 ohms, and is therefore suitable for all accurate 4-decade Wheatstone bridge measurements.

2. Is exceedingly accurate, serviceable and durable and may be handled without risk of damage, and hence unless grossly abused, its lifetime is practically unlimited.

3. Reasonable in first cost and has practically no maintenance cost.

4. Direct reading and much more responsive than suspension-type reflecting galvanometers.

5. Has glass front so that principle of operation may be readily explained and understood.

6. Its readings may be readily interpolated, and therefore in emergency it may be used as a high-sensitivity milliammeter, etc.

7. Has a zero correcting adjustment.

8. If required same instrument can be furnished with three self-contained damping shunts at special price.

List price $18 each f.o.b. Newark.

WESTON STUDENT'S GALVANOMETER

Model 375

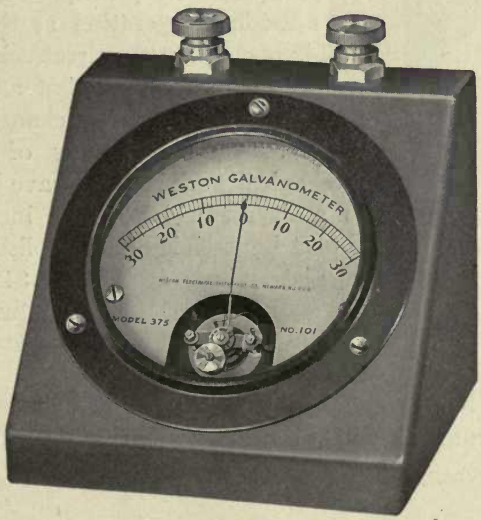

Fig. 9.

1. This instrument is of the permanent-magnet movable-coil type. It is mounted on a wooden base, at a convenient angle for reading.

2. It has a zero-in-center scale; length 30–0–30 millimeters.

3. An e.m.f. of 1 volt will produce current giving a deflection of 1 scale division through a series resistor of 62,500 ohms.

4. Current required for 1 mm. deflection is 16 microvolts.

5. Resistance of instrument is approximately 29 ohms.

6. This instrument may be used as a current detector or a galvanometer for Wheatstone bridge resistance measurements; as a means for measuring insulation resistance, for the measurement of very small currents, etc.

7. The accuracy obtained with it in bridge work for any resistances up to 2000 ohms is greater than $\frac{1}{2}$ of 1 per cent.

List price, $9.

WESTON MINIATURE PRECISION DIRECT-CURRENT INSTRUMENTS

Model 280

Fig. 10.—Model 280 Triple Range Portable Volt-Ammeter.

Although the instruments of this group are the same in principle and have the same mode of operation as the early and well-known Weston direct-current instruments, their general design and construction have been greatly changed and improved. The refinements of design and mechanical work in them have been carried to a degree which seems incredible and almost impossible of accomplishment.

List prices are from $12.50 for a single-range ammeter or voltmeter to $27 for a triple-range volt-ammeter, with intermediate prices according to the number of ranges required.

Bulletin No. 8, giving a complete description and price list of these instruments, will be sent upon application.

WESTON MINIATURE SWITCHBOARD VOLTMETERS, AMMETERS AND MILAMMETERS

MODEL 267

FIG. 11.—Model 267 Switchboard Voltmeter, Front View.

FIG. 12.—Model 267 Switchboard Voltmeter, Back View.

This group of instruments consists of a variety of ranges, of small switchboard ammeters and voltmeters suitable for use in small isolated plants, signal systems, battery charging panels, and for all kinds of service where small switchboard-indicating, instruments are needed, *and will also appeal to Science Teachers.*

Made only in single ranges, with back connections. See Figs. 11 and 12.

List price $10.50. Bulletin supplied upon request.

WESTON PORTABLE A.C. VOLTMETERS, AMMETERS AND MILLI-AMMETERS

MODEL 155

Although specially designed for alternating-current measurements, these instruments may also be used with direct current. See Figs. 13 and 14.

They are of the "soft-iron" or electro-magnetic type, and are so excellently constructed that they are superior to many imitations of the Weston direct-current permanent-magnet instrument.

They are remarkably accurate, and may be relied upon to within $\frac{1}{2}$ of 1 per cent.

While primarily intended for A.C. work, they may be used with direct current with an average error of not more than $1\frac{3}{4}$ per cent.

These instruments necessarily do not have evenly divided scales, but are so contrived that their scales are almost absolutely proportional throughout about four-fifths of their length (the working part of the scale).

The moving system is exceedingly light and compact.

These instruments may be used on circuits of any frequency within the limits of engineering practice of to-day.

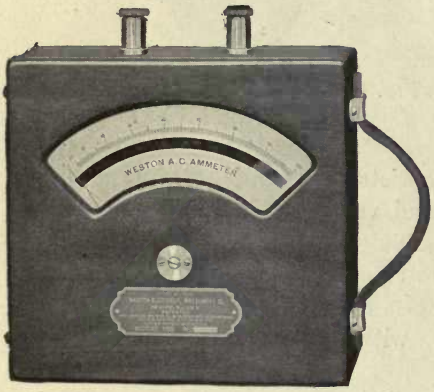

FIG. 13.

FIG. 14.

Their action is perfectly " dead beat."

They are extremely sensitive and quickly respond to the most minute as well as the greatest fluctuations in current strength or potential difference on the circuit.

List prices are from $17 to $30, according to range of instrument required.

Circular No. 7 giving a complete price list and description of these instruments, and also of similar ones designed for switchboard use, will be mailed on application.

WESTON A.C. SWITCHBOARD VOLTMETERS AND AMMETERS

Model 156

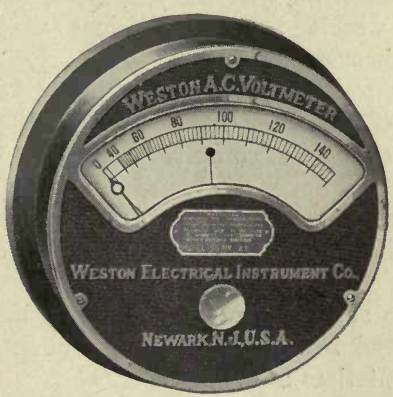

Fig. 15.

A Few Important Points of Superiority of the Model 156 Voltmeters and Ammeters

These instruments are the two new lines intended for use as ammeters and voltmeters on alternating-current switchboards, but they may also be used with *direct-current*. They are of the "soft-iron or electro-magnetic type," but in their electrical and mechanical characteristics they are so far in advance of all preceding forms of soft-iron instruments as to mark a new epoch in that type of instrument.

1. *No Inductance Error.* That is, the errors in the indications of these instruments when used for all frequencies met with in ordinary engineering practice are entirely negligible.

2. *No Discernible Working Error.* That is, they indicate the same whether left in circuit for a minute, or permanently.

3. *No Chamber Error.* That is, the error for any reasonable change in the temperature of the surrounding atmosphere of the room or chamber where used is negligible. In fact a change of 100° F. will cause an error of less than ½ of 1 per cent on a voltmeter with a range of 150 volts.

4. *Entirely Dead Beat.* That is, they are in this respect the

equal of any of the permanent magnet direct-current instruments of Weston manufacture.

5. *Remarkably Uniform Scale.* In this respect also these instruments surpass all others. A reference to the facsimile scales will demonstrate that on the upper four-fifths portion of the scale (the working part) the divisions are so nearly uniform as to warrant this characterization.

6. All other sources or causes of error commonly found in instruments of the same class and now in general use, are either wholly eliminated or so far reduced as not to be discernible on the scale.

List prices are from $13.50 upwards, according to range.

Catalog giving complete description and price lists mailed on application.

The principle of operation of these alternating-current instruments is described in Monograph B–4, and beautiful phantom views of their interiors are shown.

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